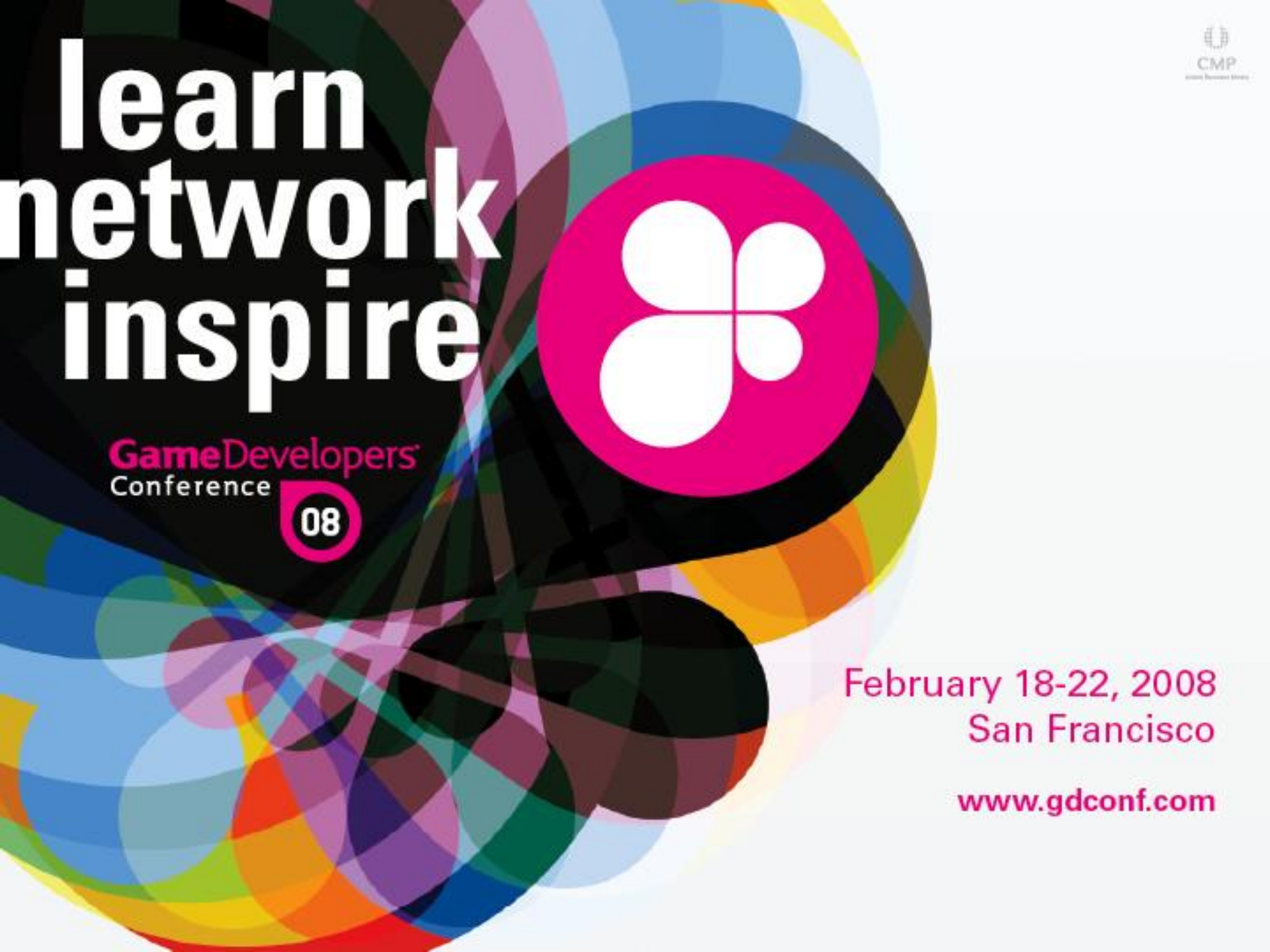
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Harnessing the Power of Multiple GPUs

Games Developer Conference 2008
Holger Gruen, holger.gruen@amd.com

Material:
Holger Gruen,
Jon Story, jon.story@amd.com
Ignacio Llamas, illamas@nvidia.com

Agenda

- Why MGPU?
- Driver/Programming Considerations
- Common Pitfalls & Solutions
- Conclusions
- Q&A

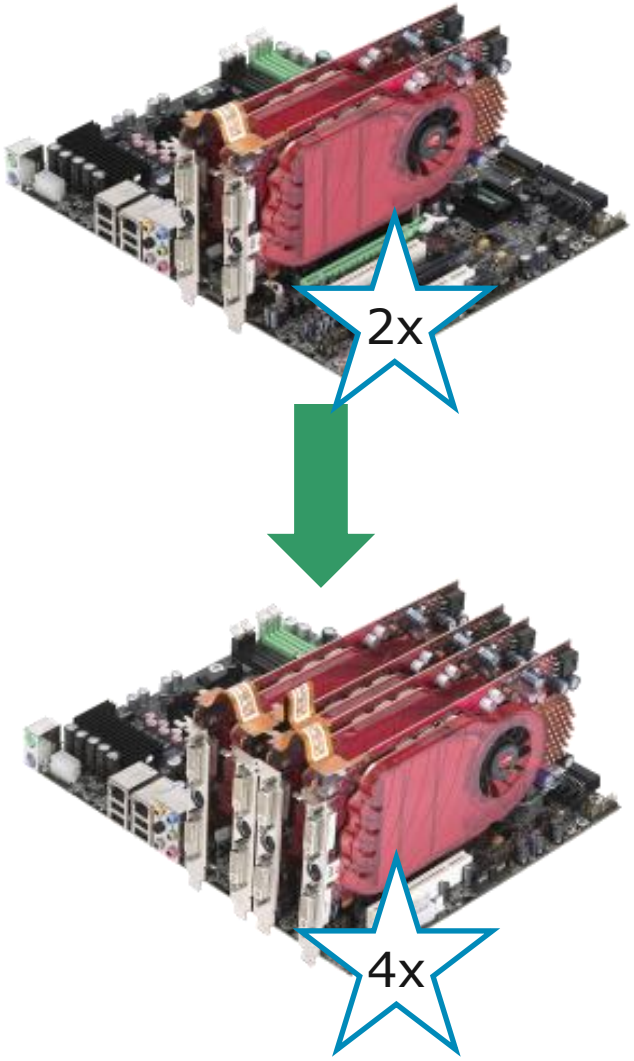
Why MGPU?

Why MGPU?

- MGPUs can be used to dramatically increase performance and visual quality
  - At higher screen resolutions
  - Especially with increased use of MSAA
- Many applications become GPU limited at higher screen resolutions/ quality settings
  - High resolution monitors => mainstream affordability
- Achieve next generation performance on today's HW
  - Prototype your next engine
  - Speed up your development time

MGPU configurations

- Multiple Boards
- Multiple GPUs per Board
- Hybrid MGPU

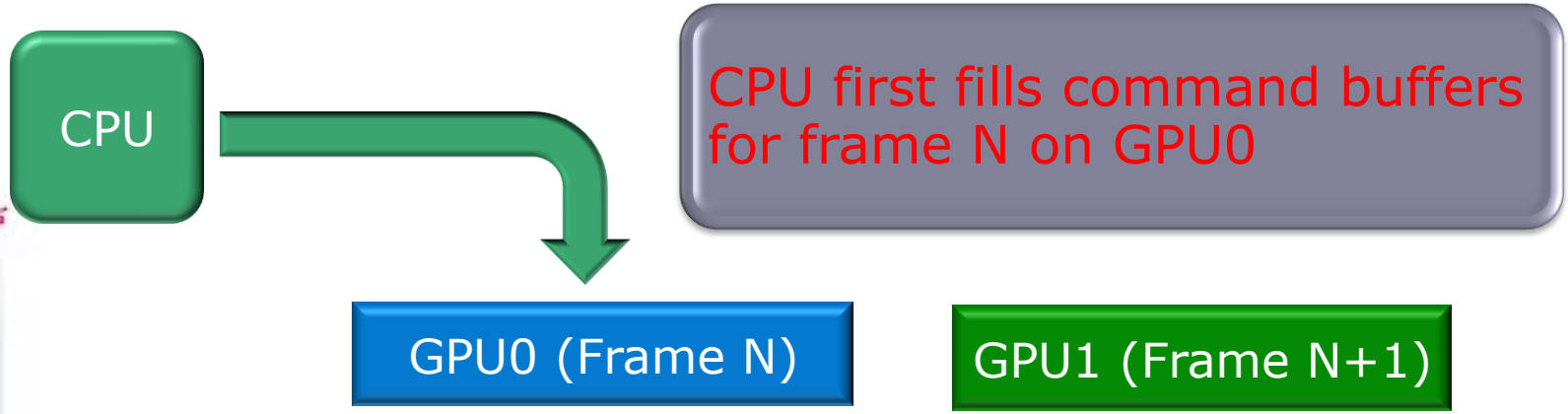


MGPU Rendering Modes

- Split Frame Rendering / Scissor
  - Screen is divided between GPUs
  - Dynamic load balancing

- Alternate Frame Rendering
  - GPUs take alternate frames
  - Highest performing mode

How does AFR Work?



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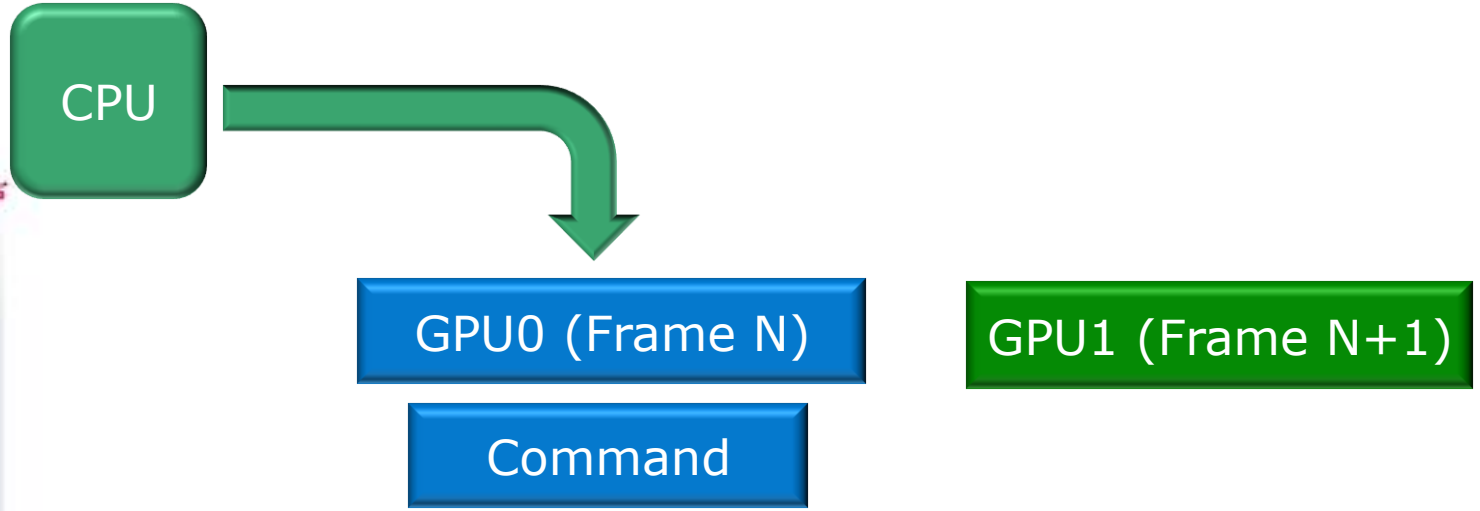

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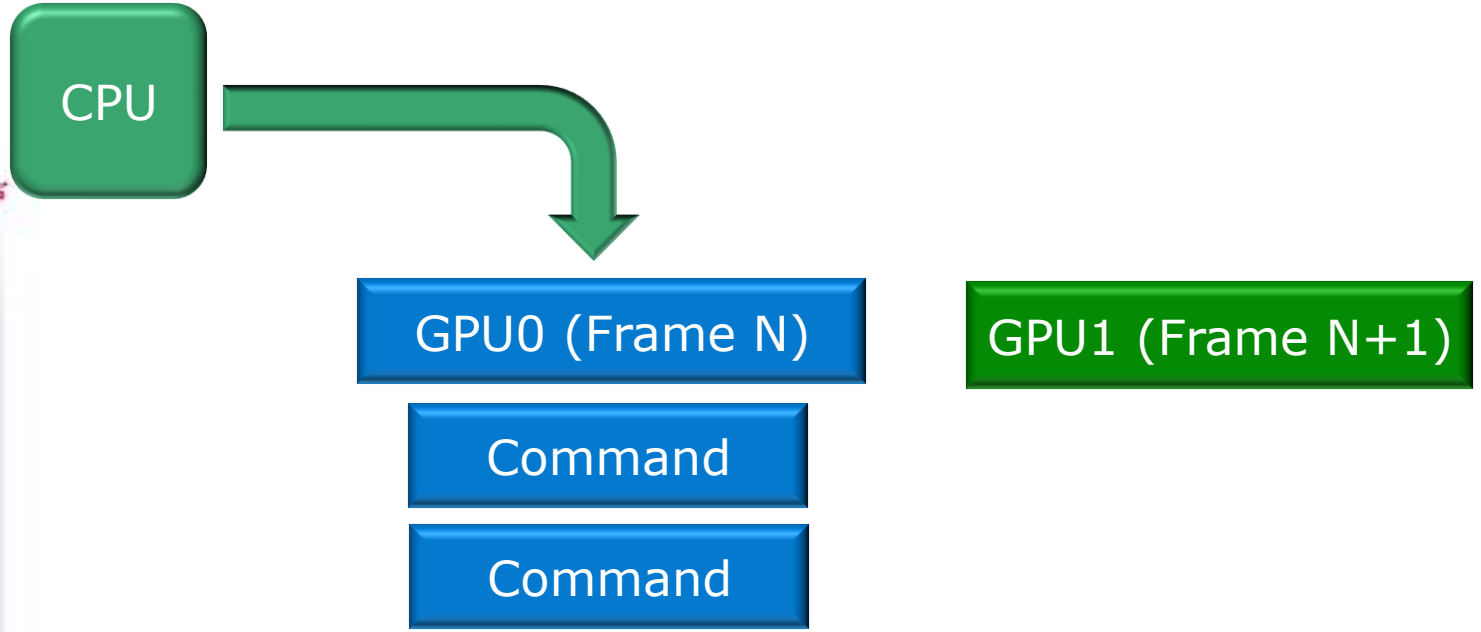

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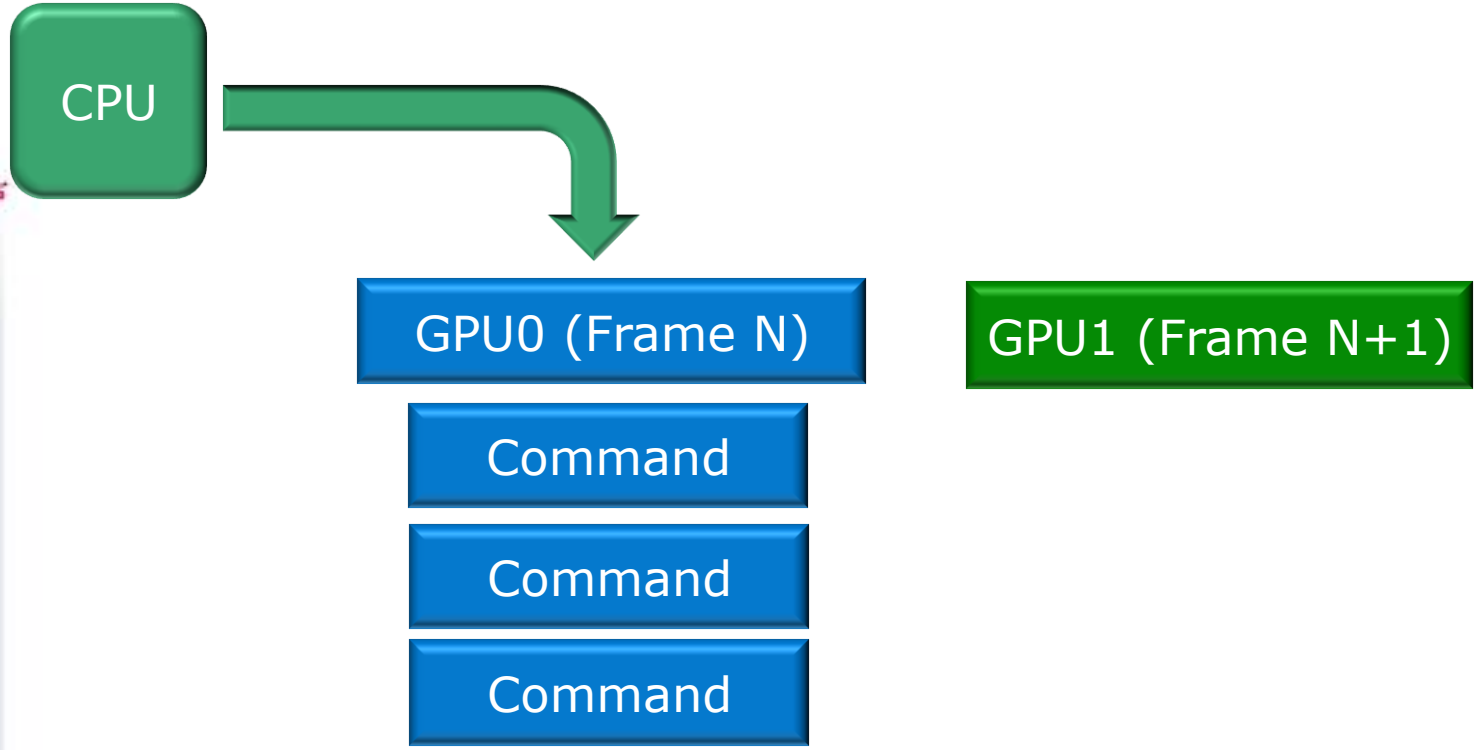

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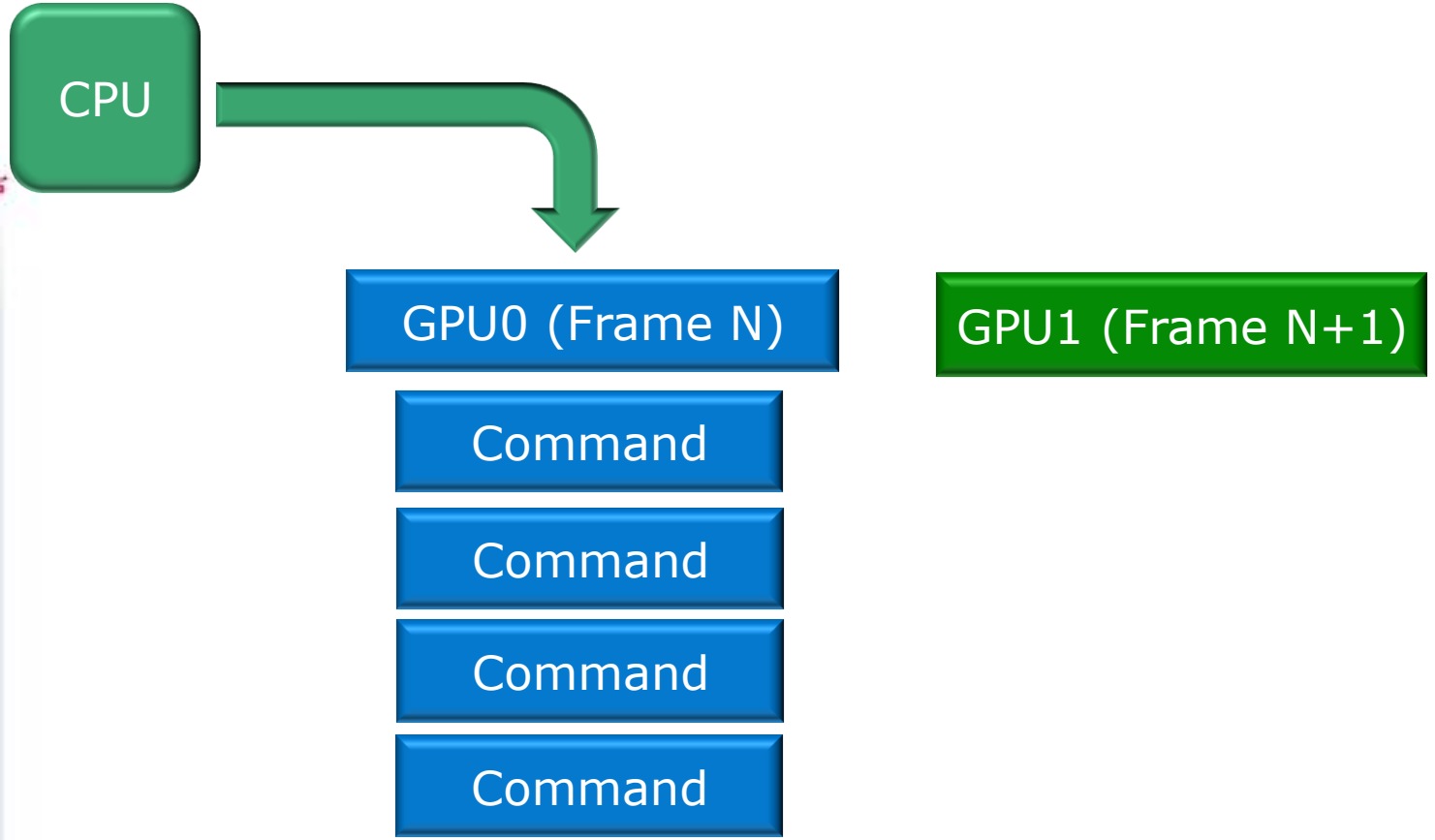

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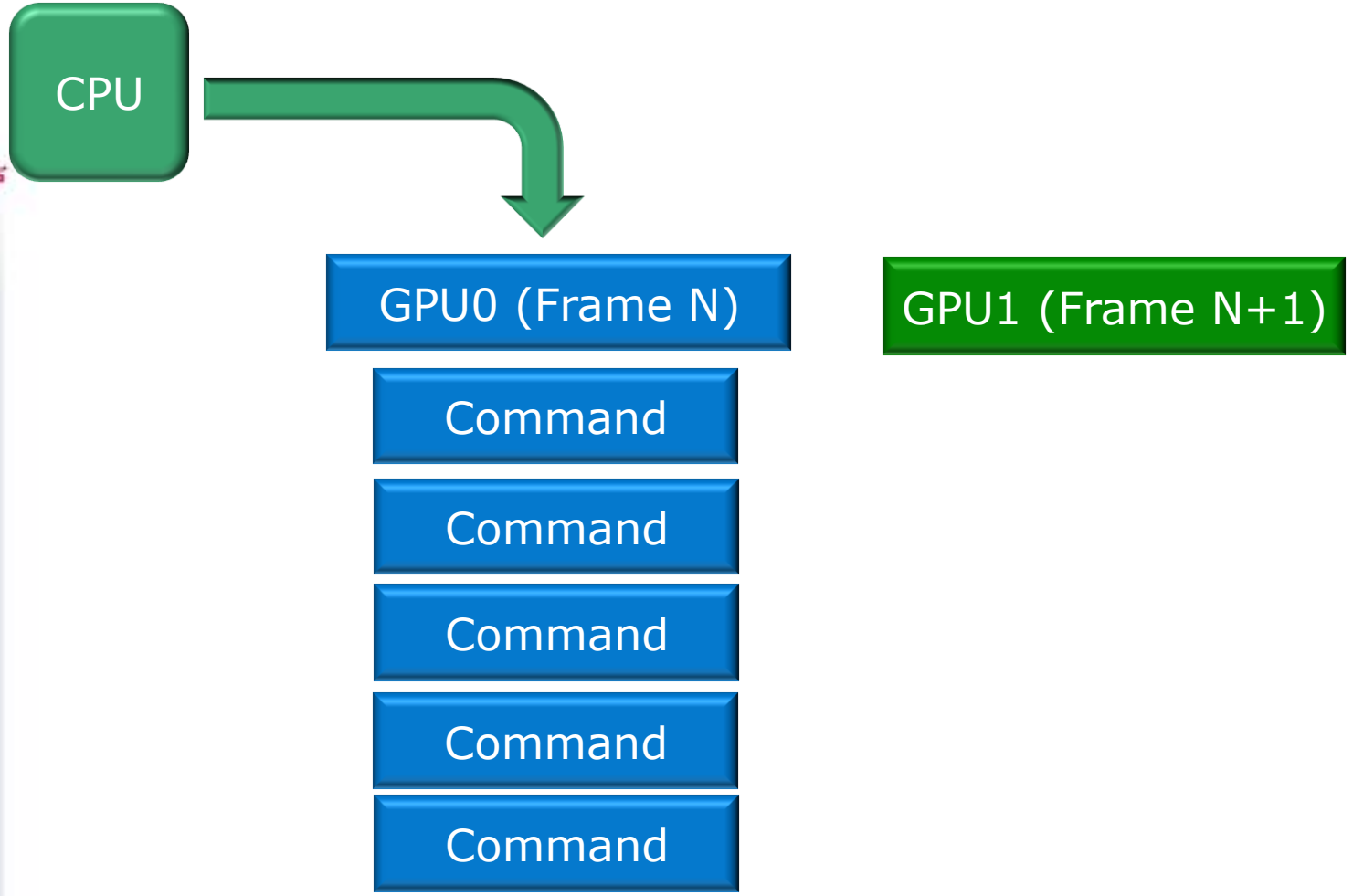

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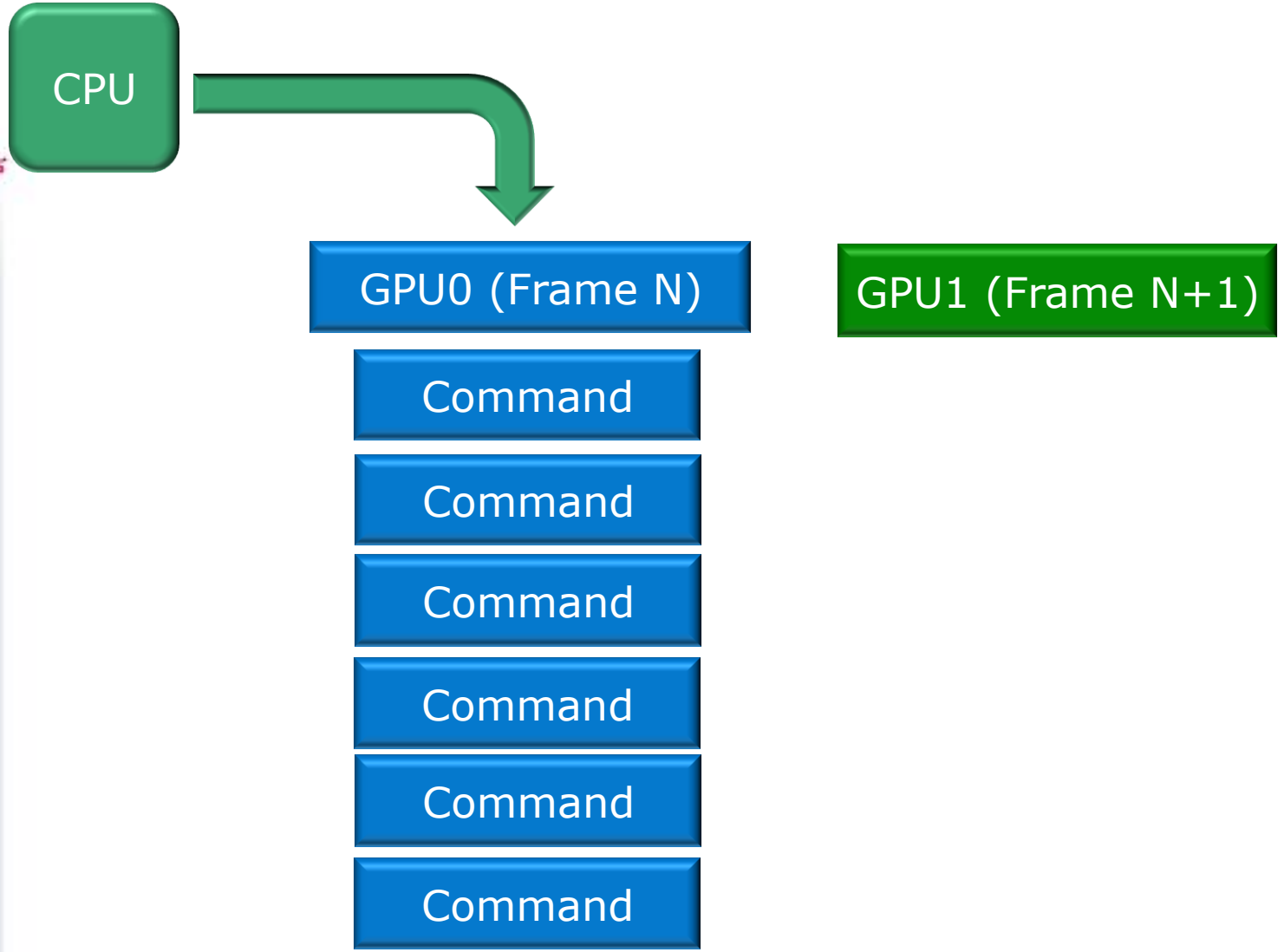

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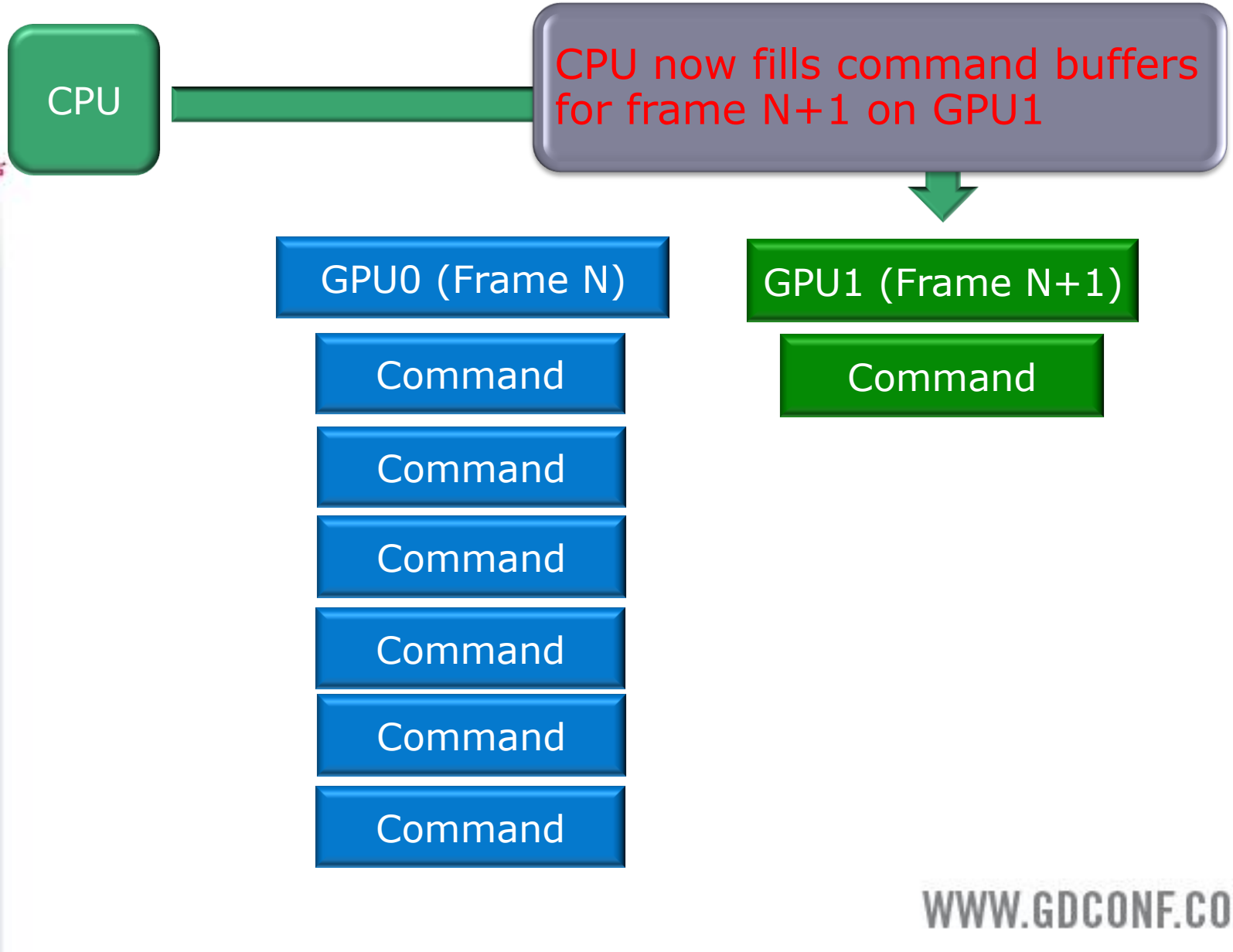

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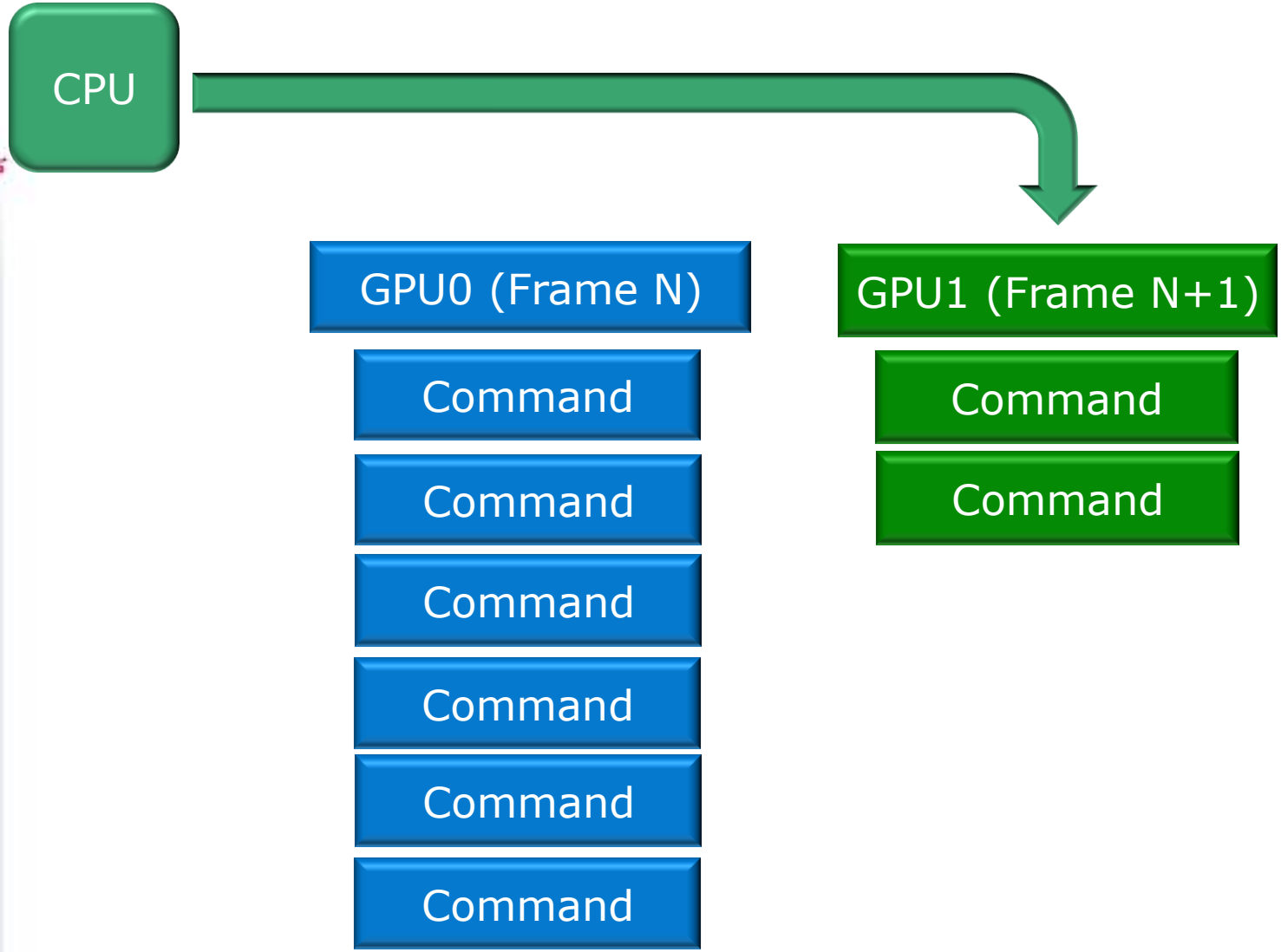

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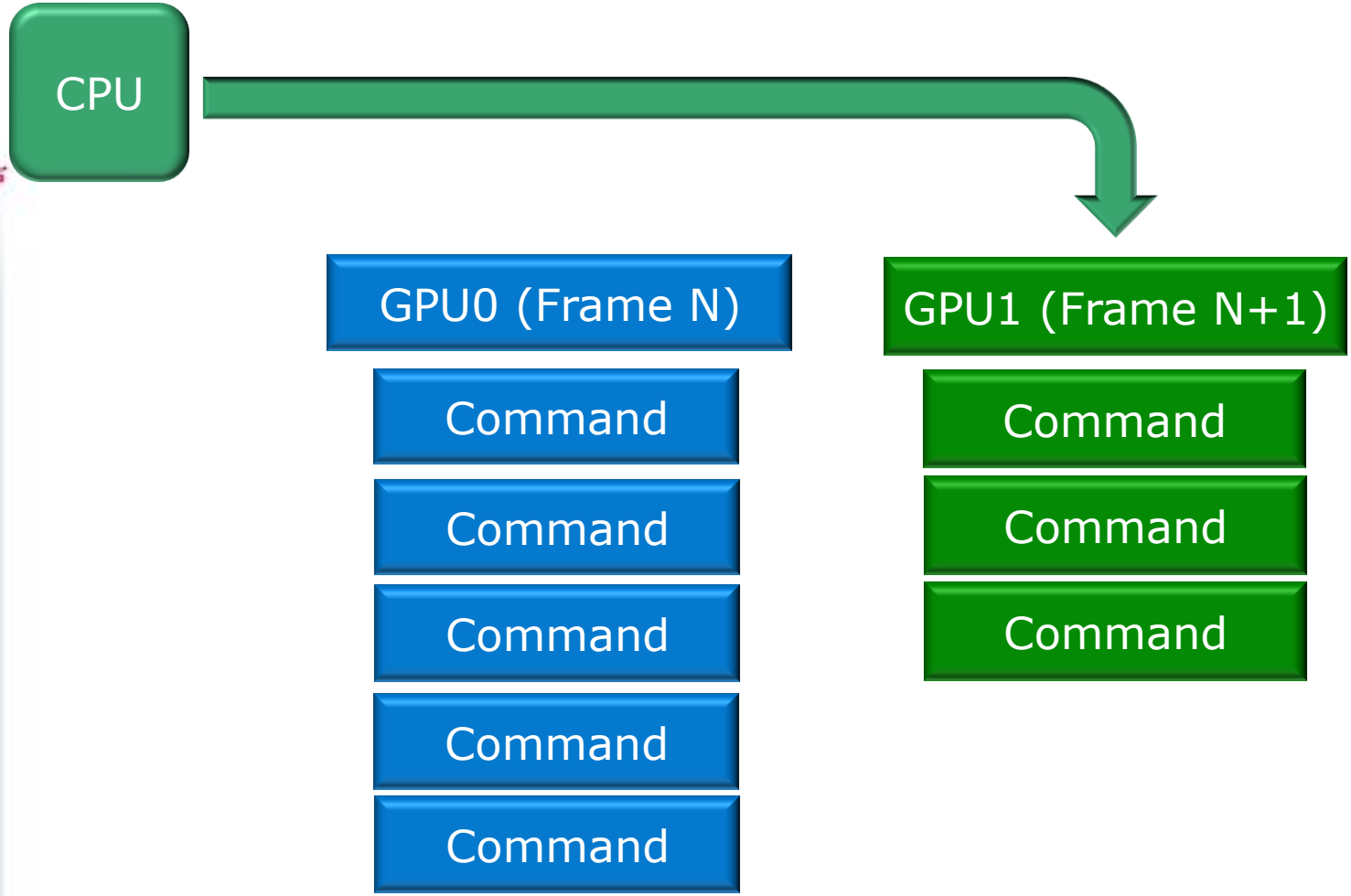

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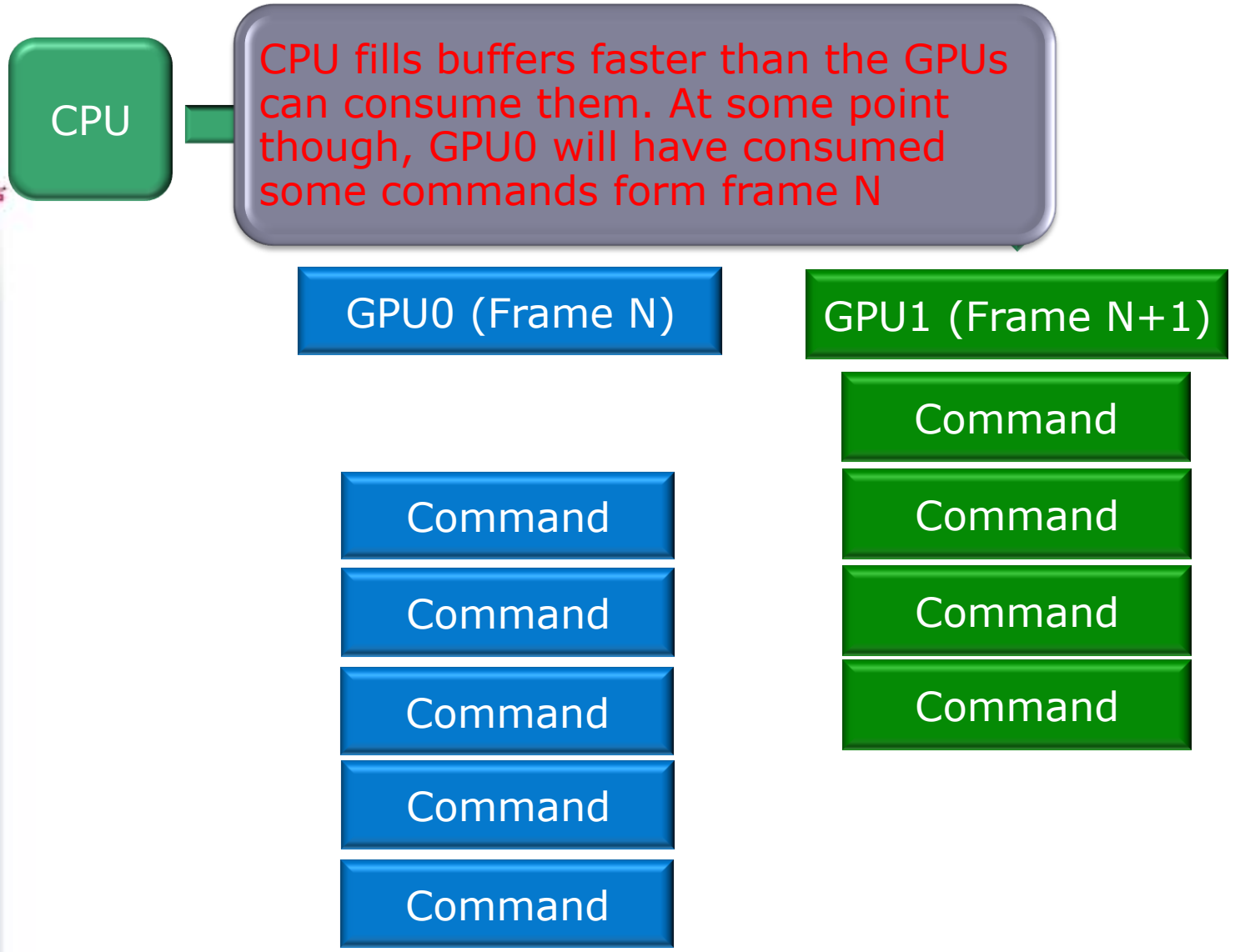

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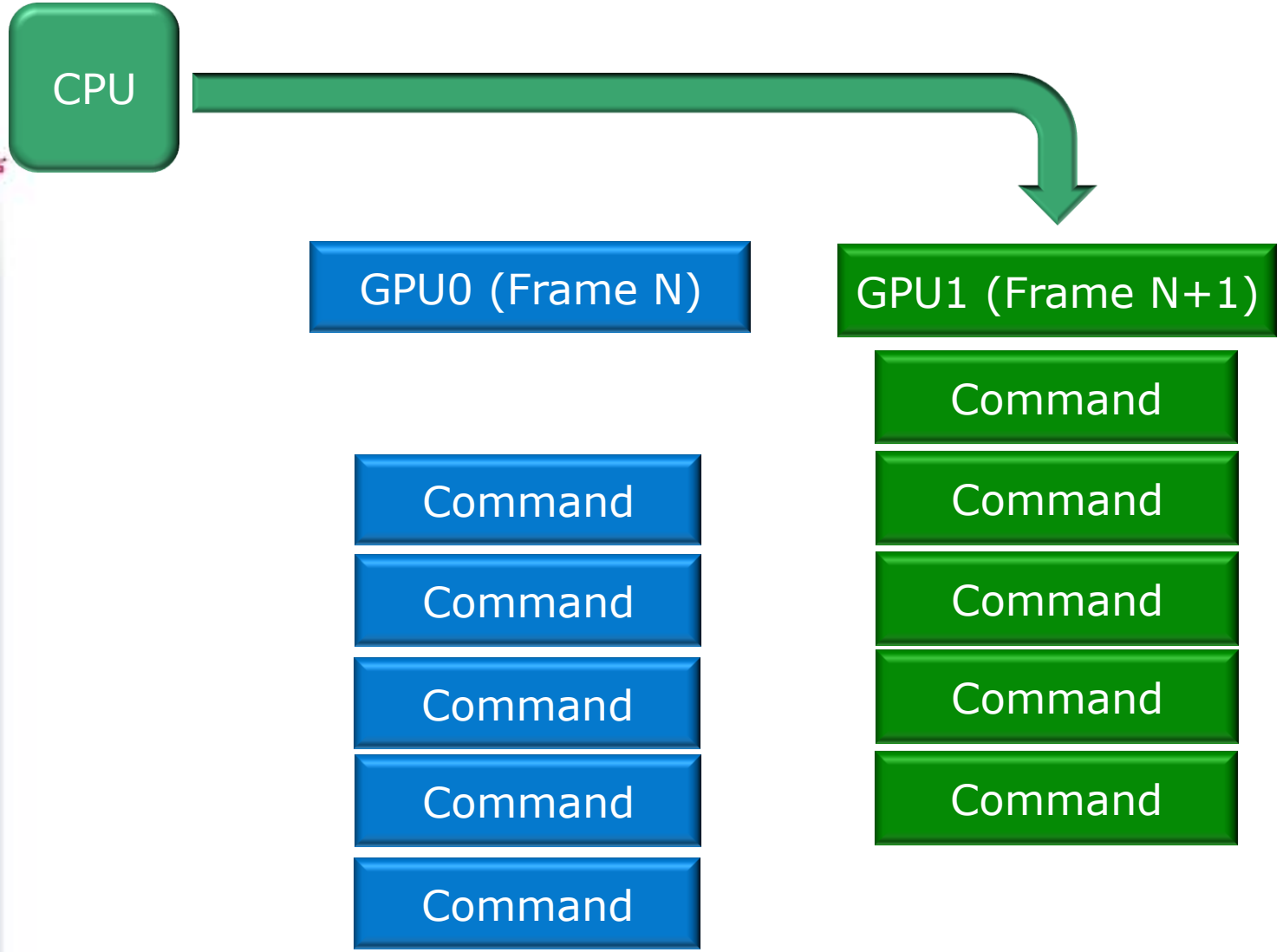

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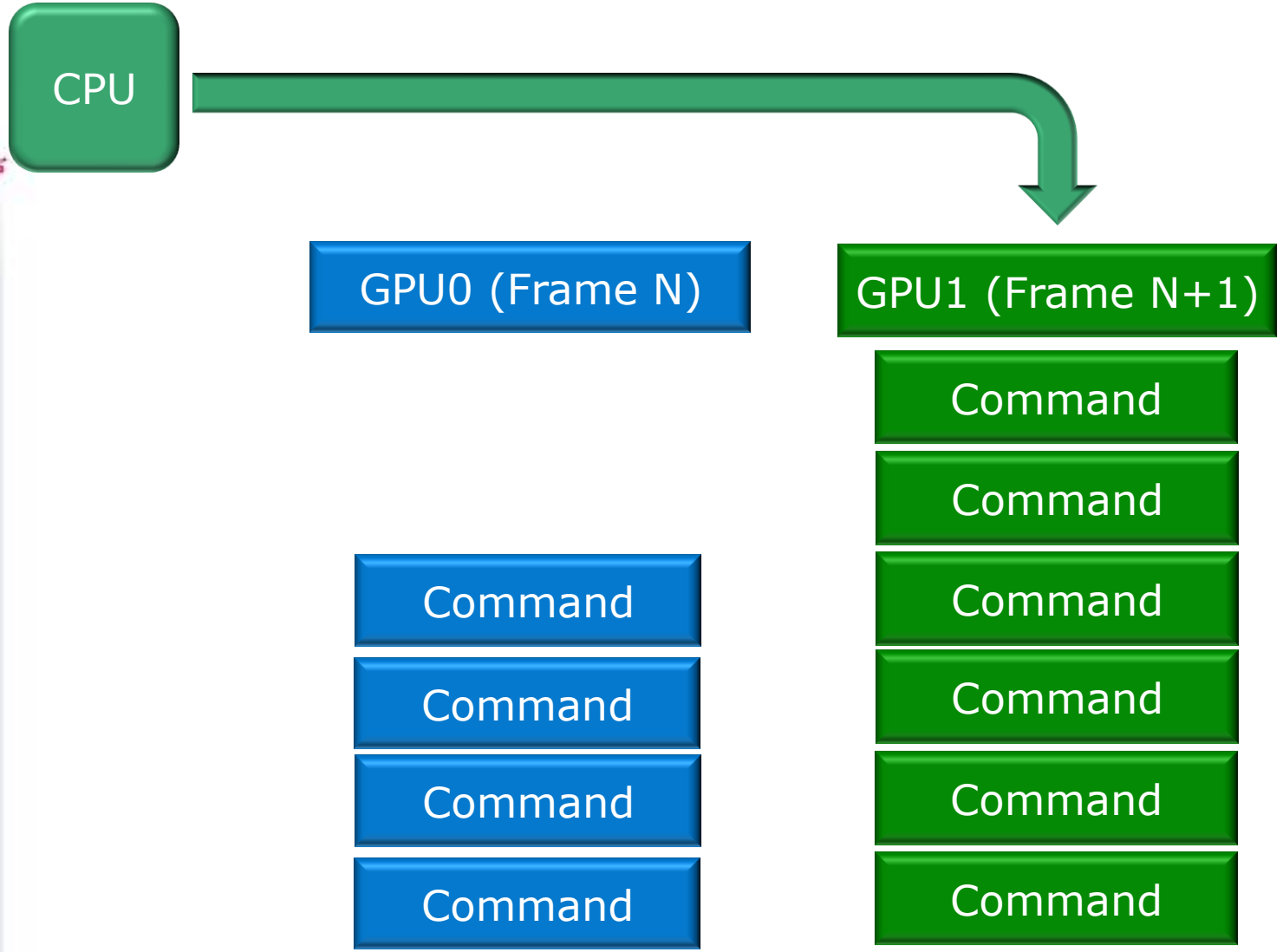


Driver/Programming Considerations

Driver modes for MGPU

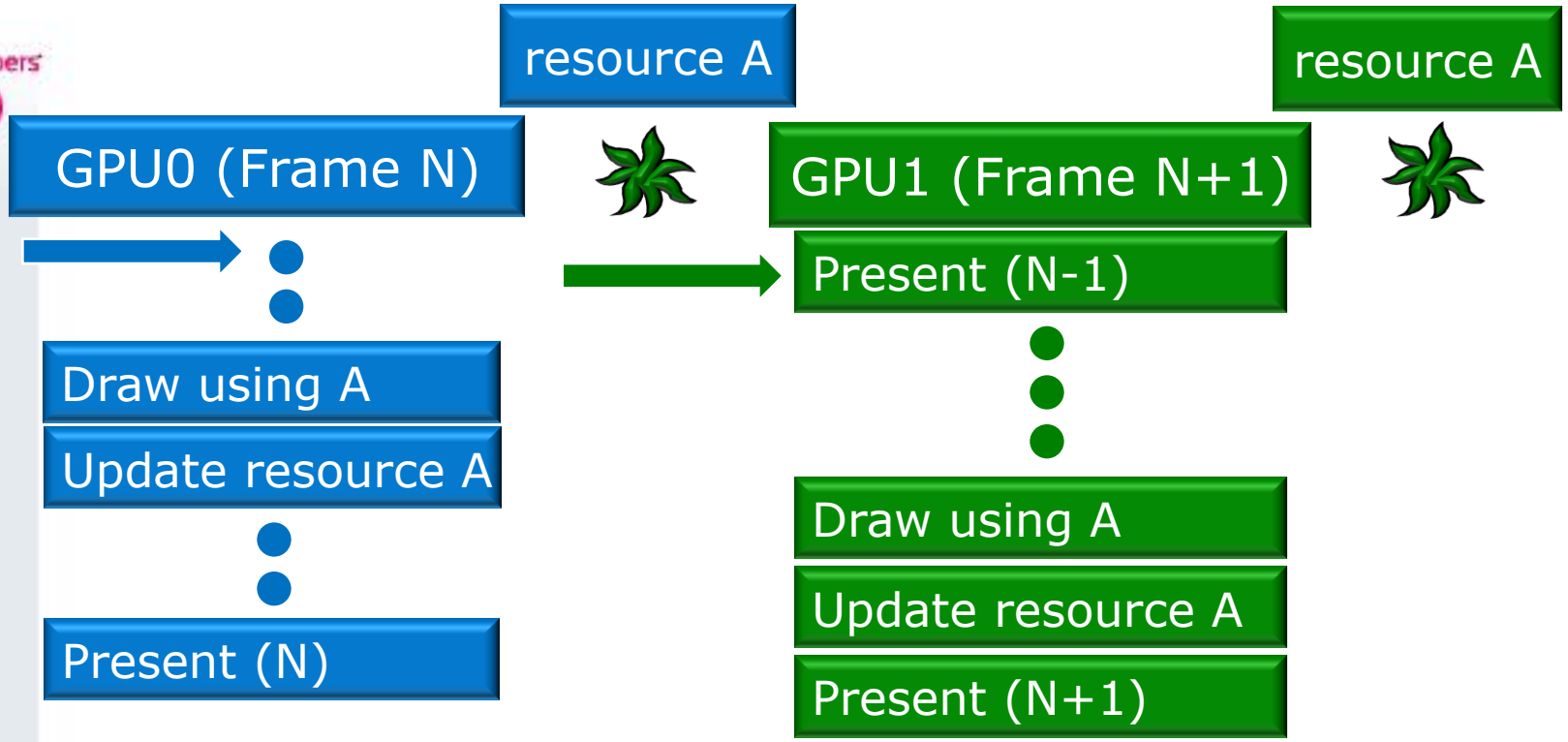
- Compatible AFR Mode
  - Default mode
  - Driver checks for AFR unfriendly behaviour
  - Will work around AFR unfriendly behaviour
- Full AFR Mode (Application Profile)
  - Driver recognises EXE name
  - Behaviour fully guided by profile
  - Best performance – no checking
  - We need developer input here!
  - Rename EXE to "AFR-FriendlyD3D.exe"
    - No checking : Speed & compatibility test

Programming for MGPU

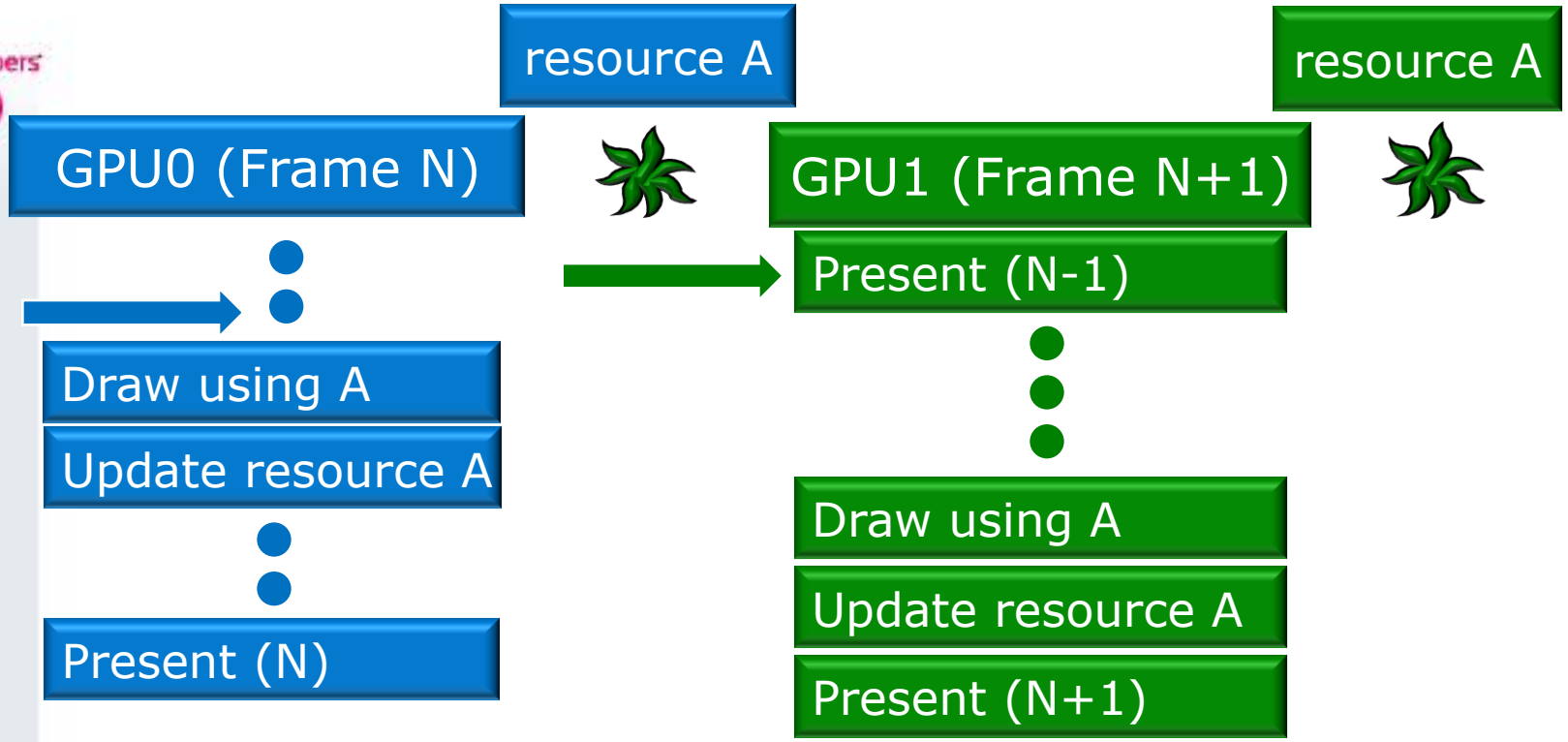
- Current MGPU setups are not shared memory architectures
  - Apps need to behave well to scale
  - Need to keep resources in sync on all GPUs
- Know what GPU(s) are rendering the current frame
  - Critical to adapt application behavior
- Use AMD / NVIDIA libraries
  - AMD: Query the number of GPUs
  - Nvidia: Query MGPU topology

Common Pitfalls & Solutions

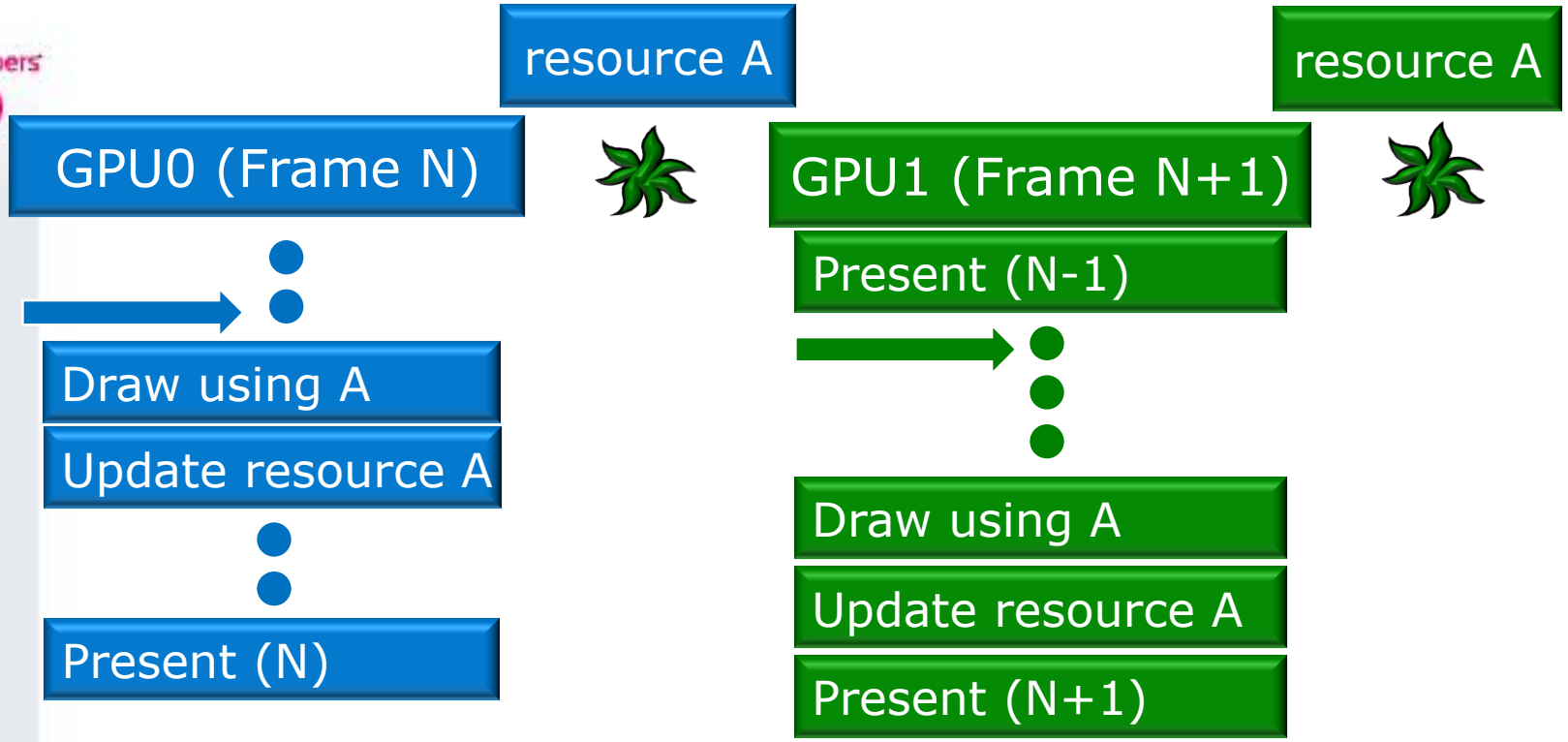
Pitfall: Dependencies Between Frames



Pitfall: Dependencies Between Frames



Pitfall: Dependencies Between Frames



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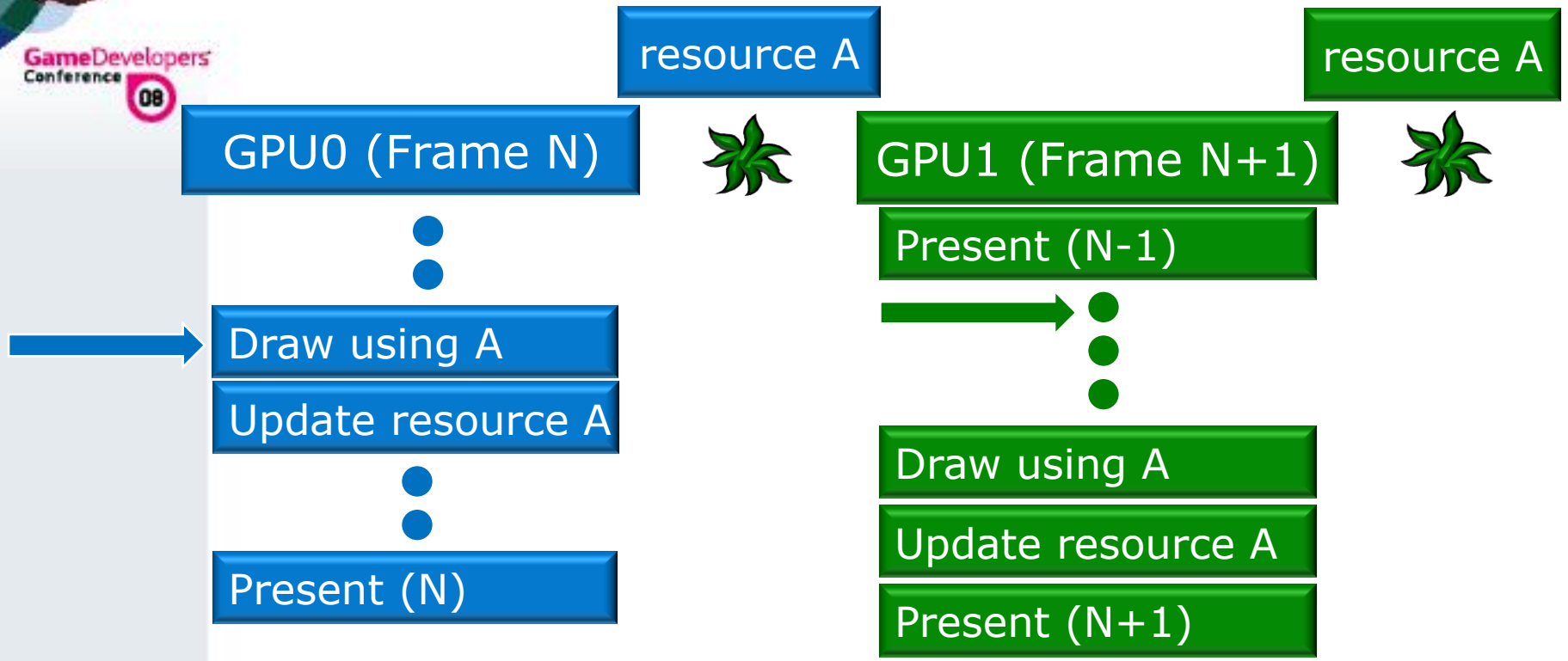

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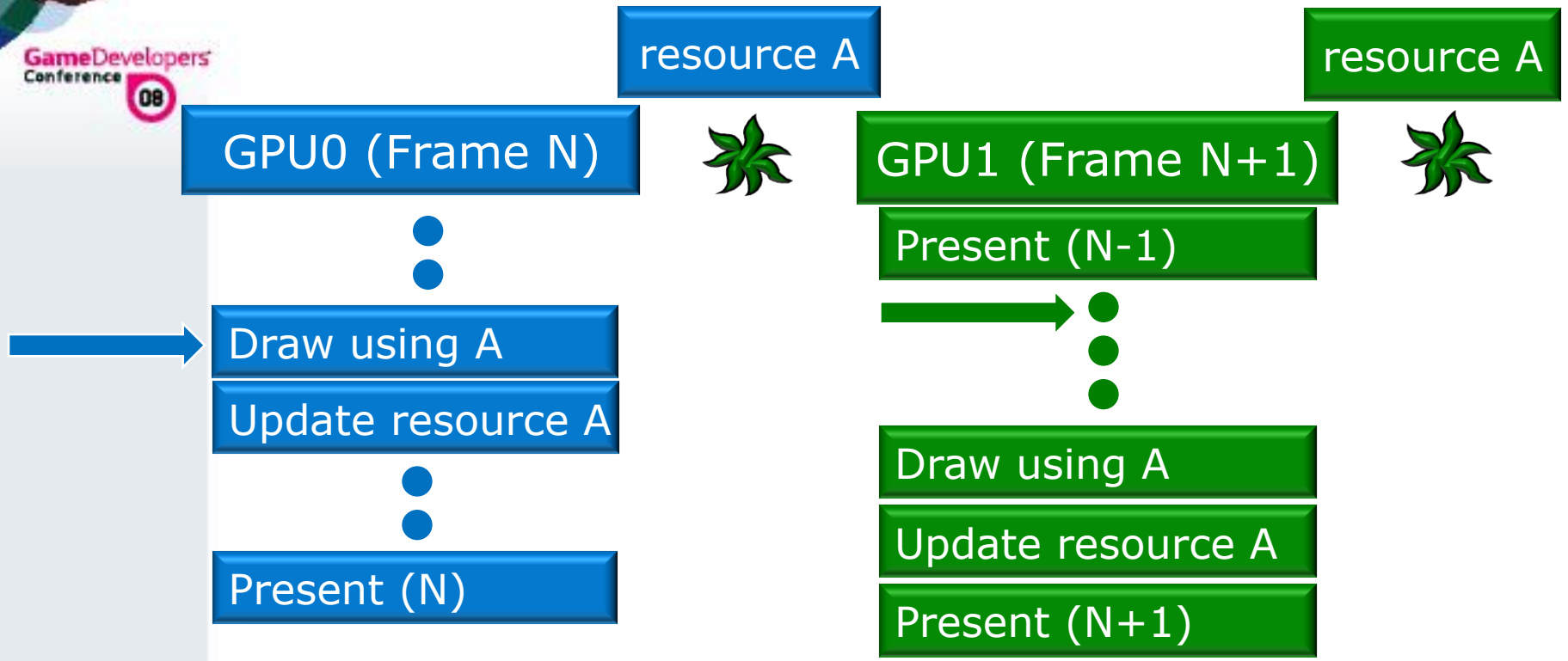

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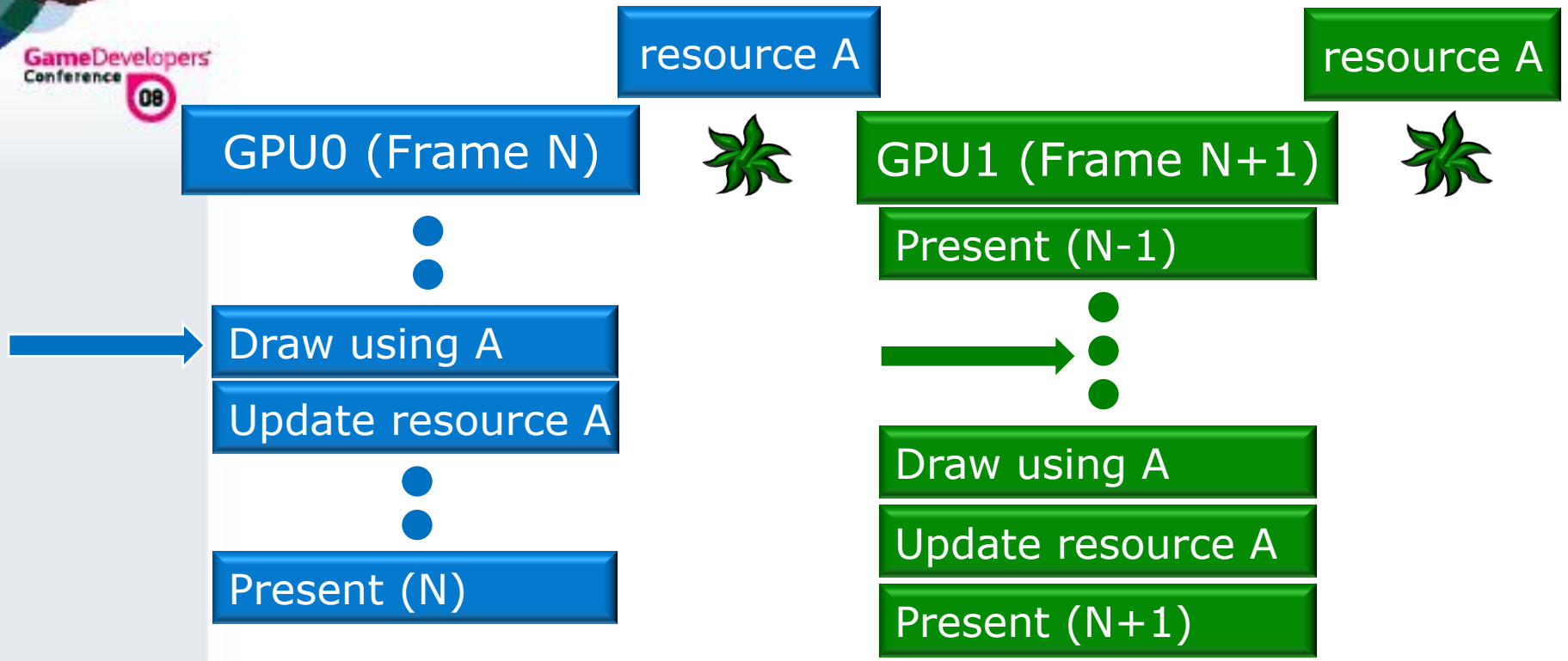

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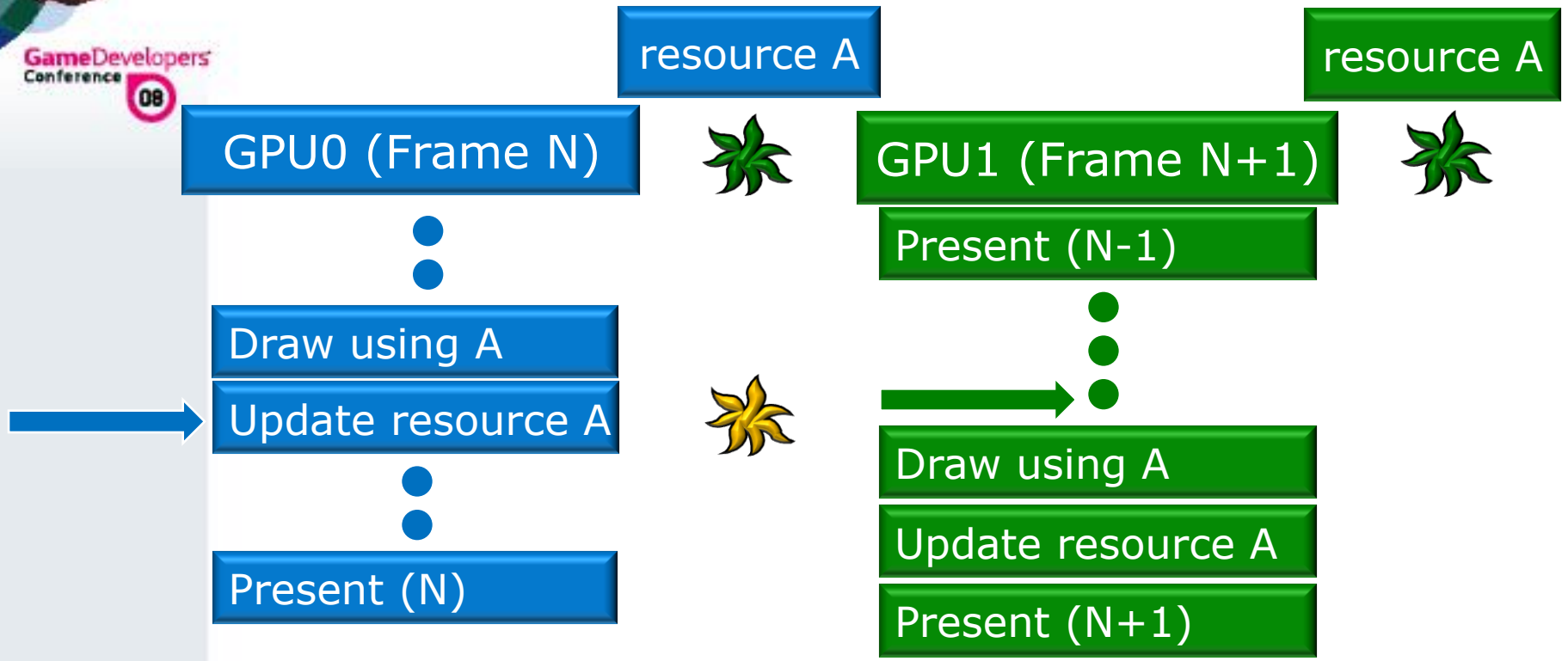

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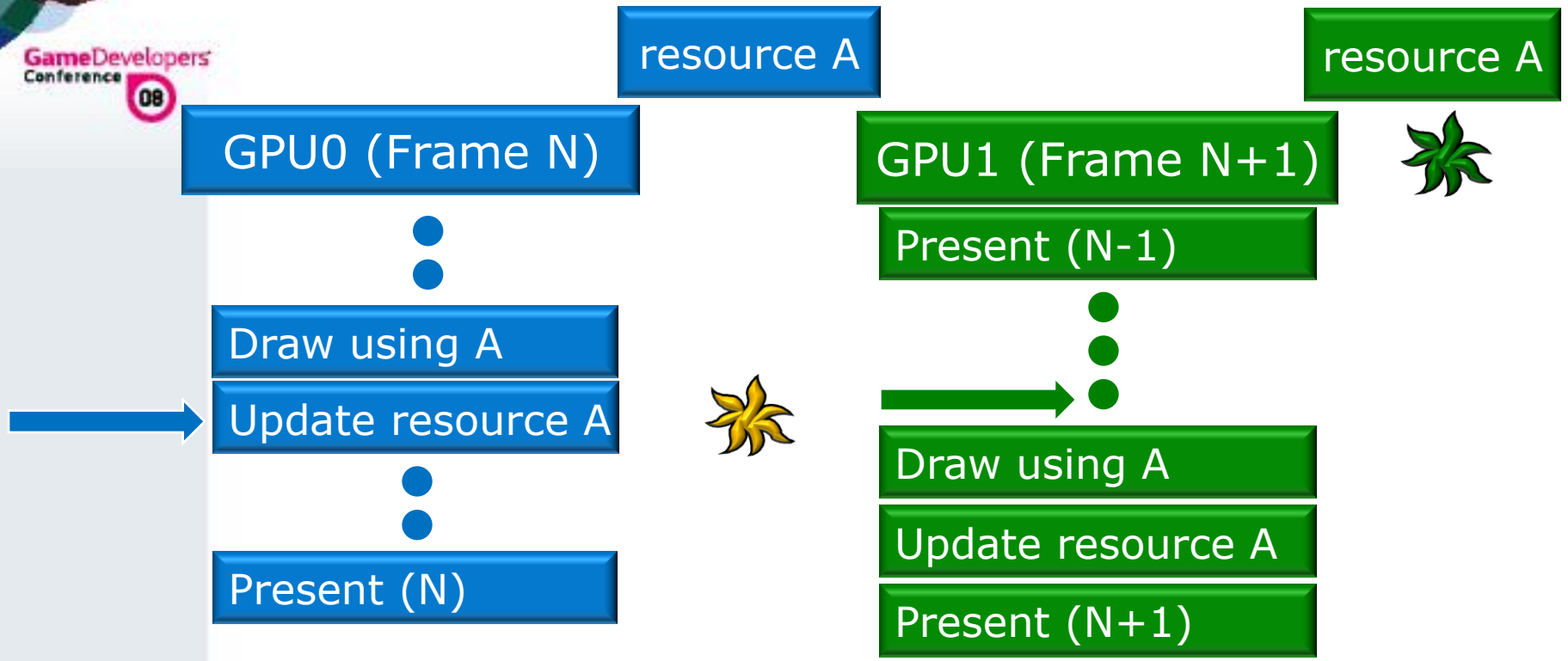

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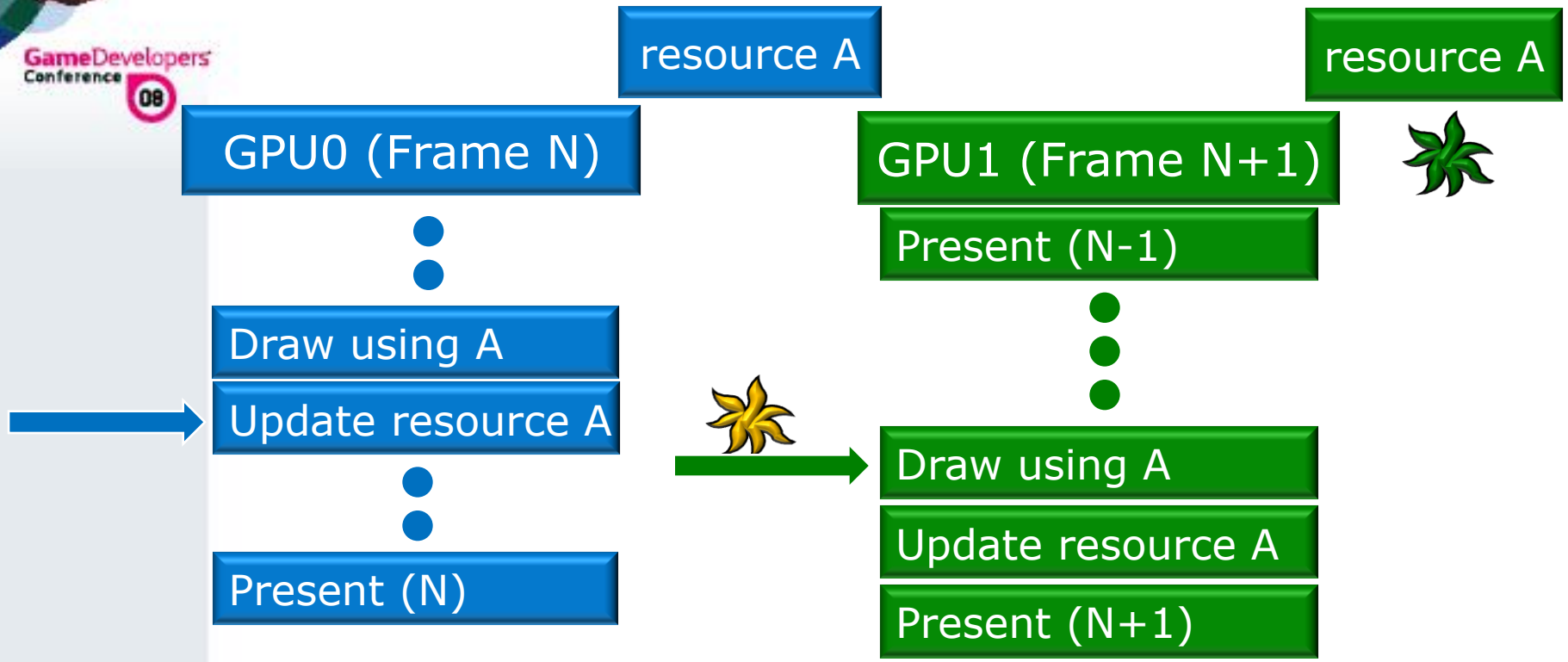

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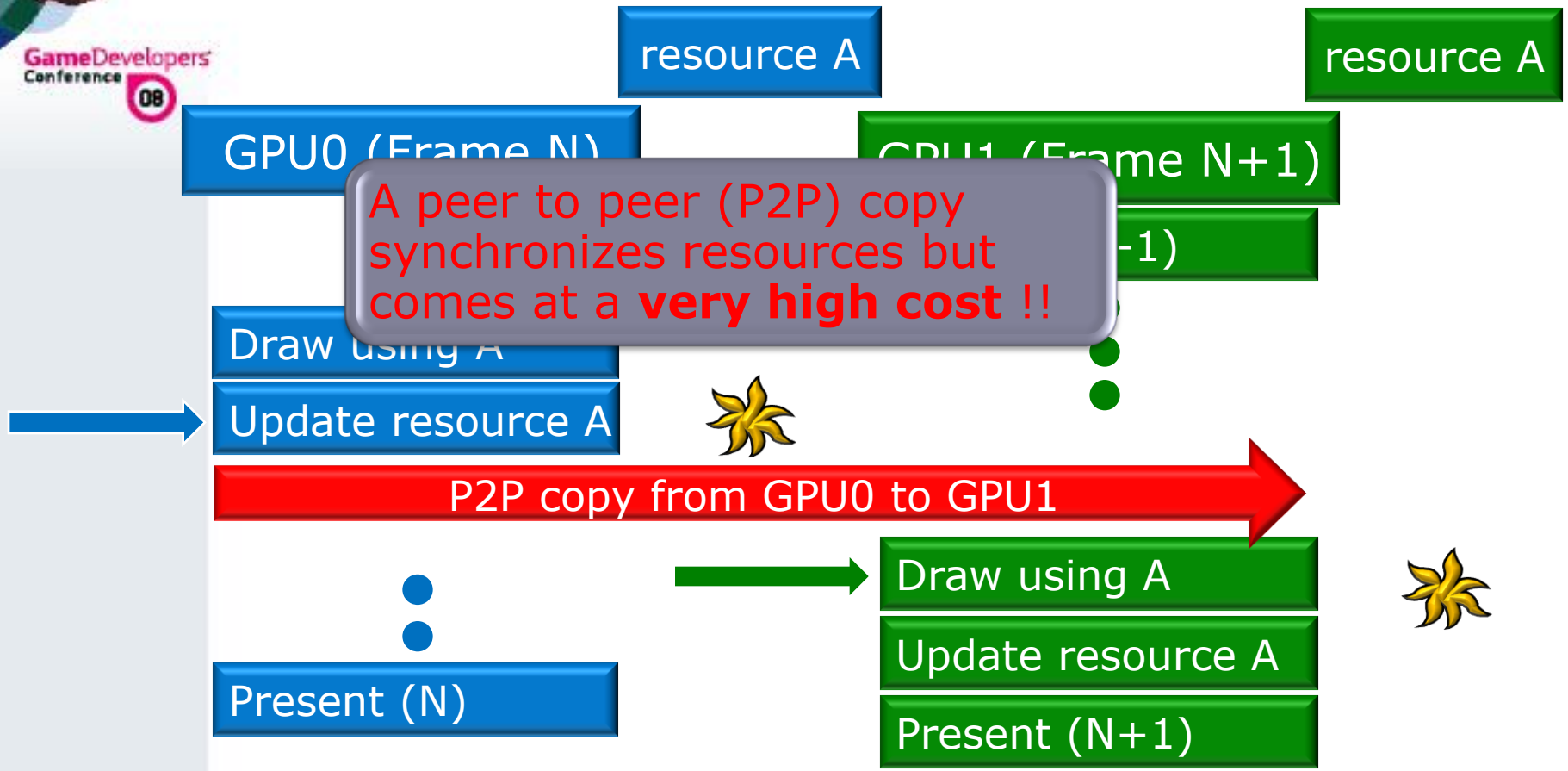
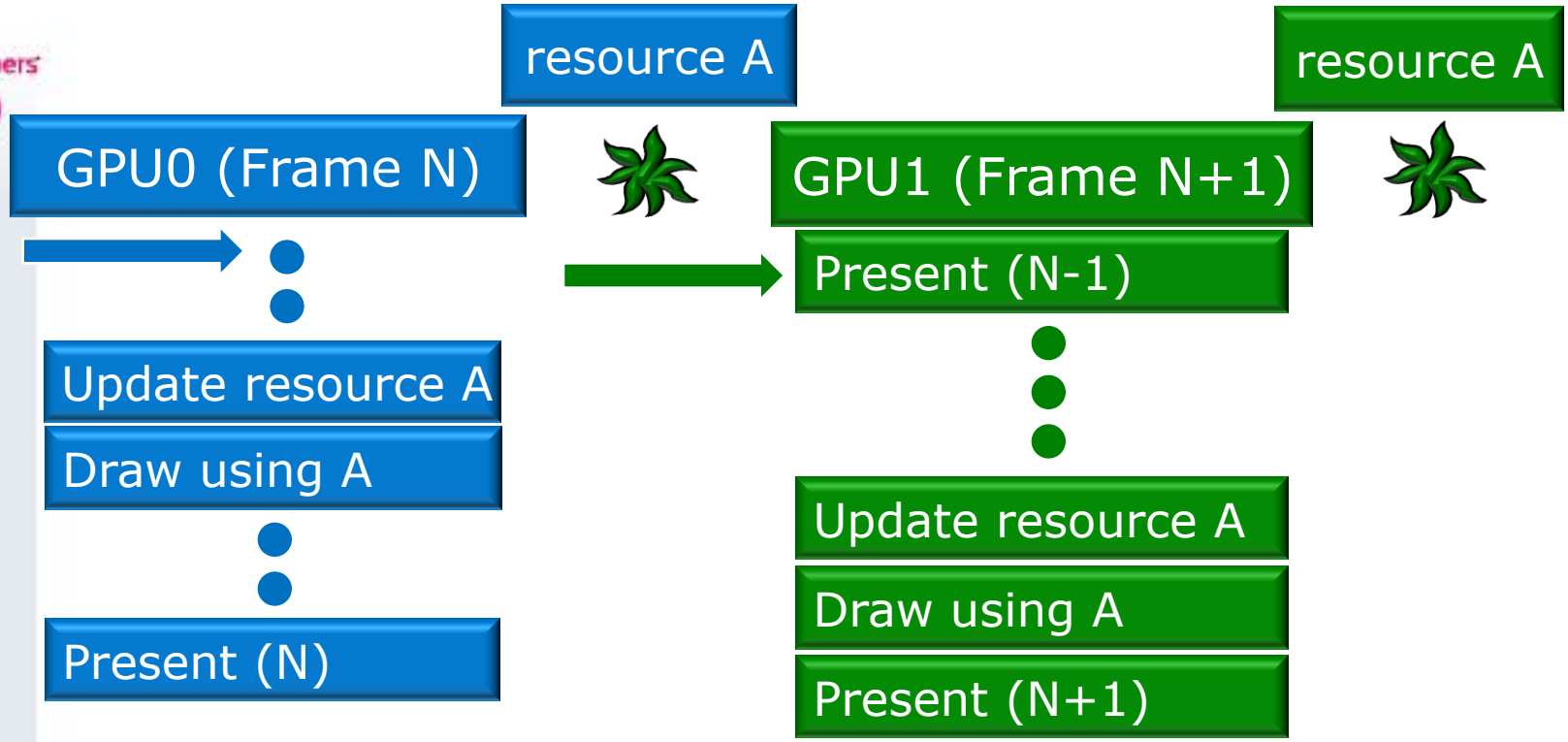


Solution: Resources that Change Every Frame



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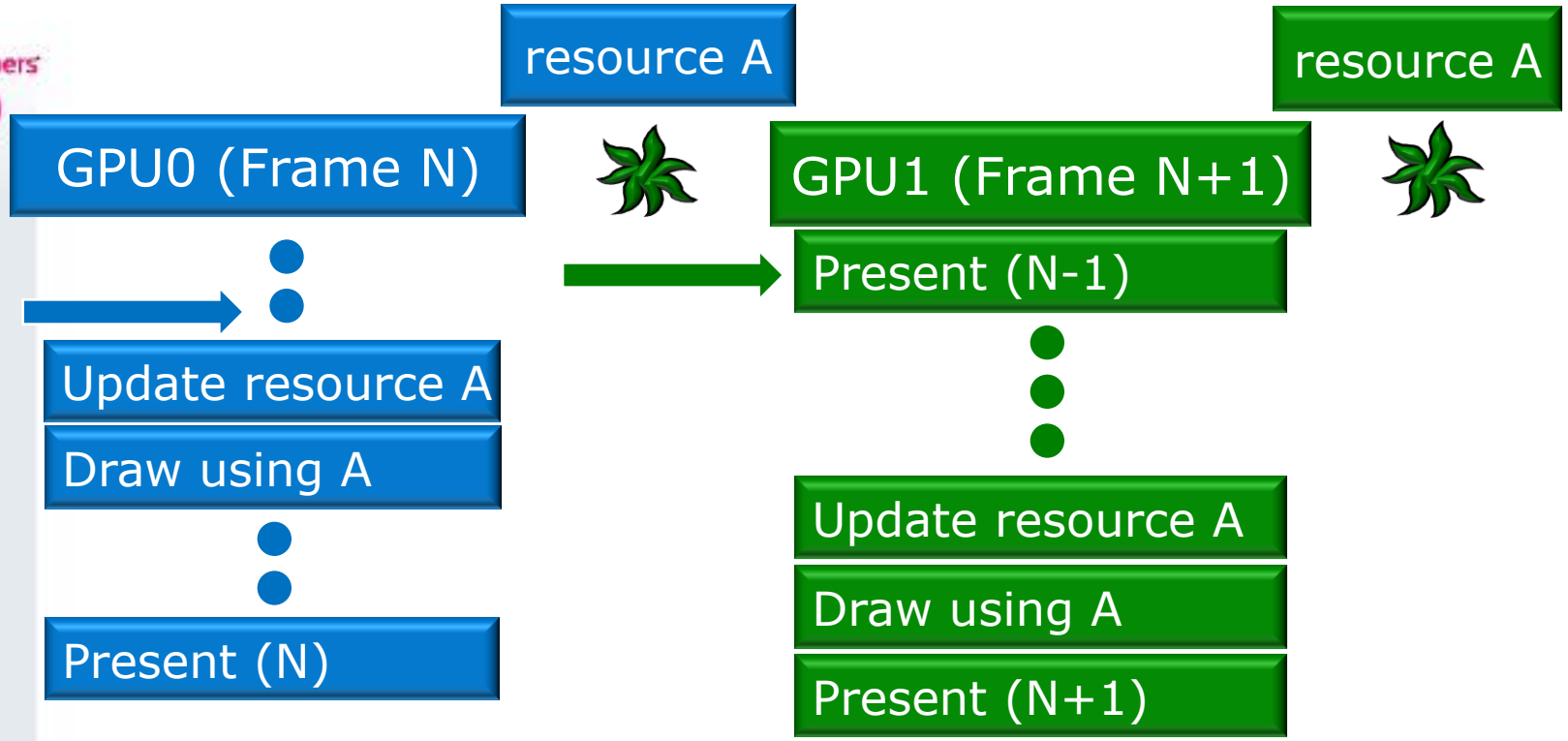
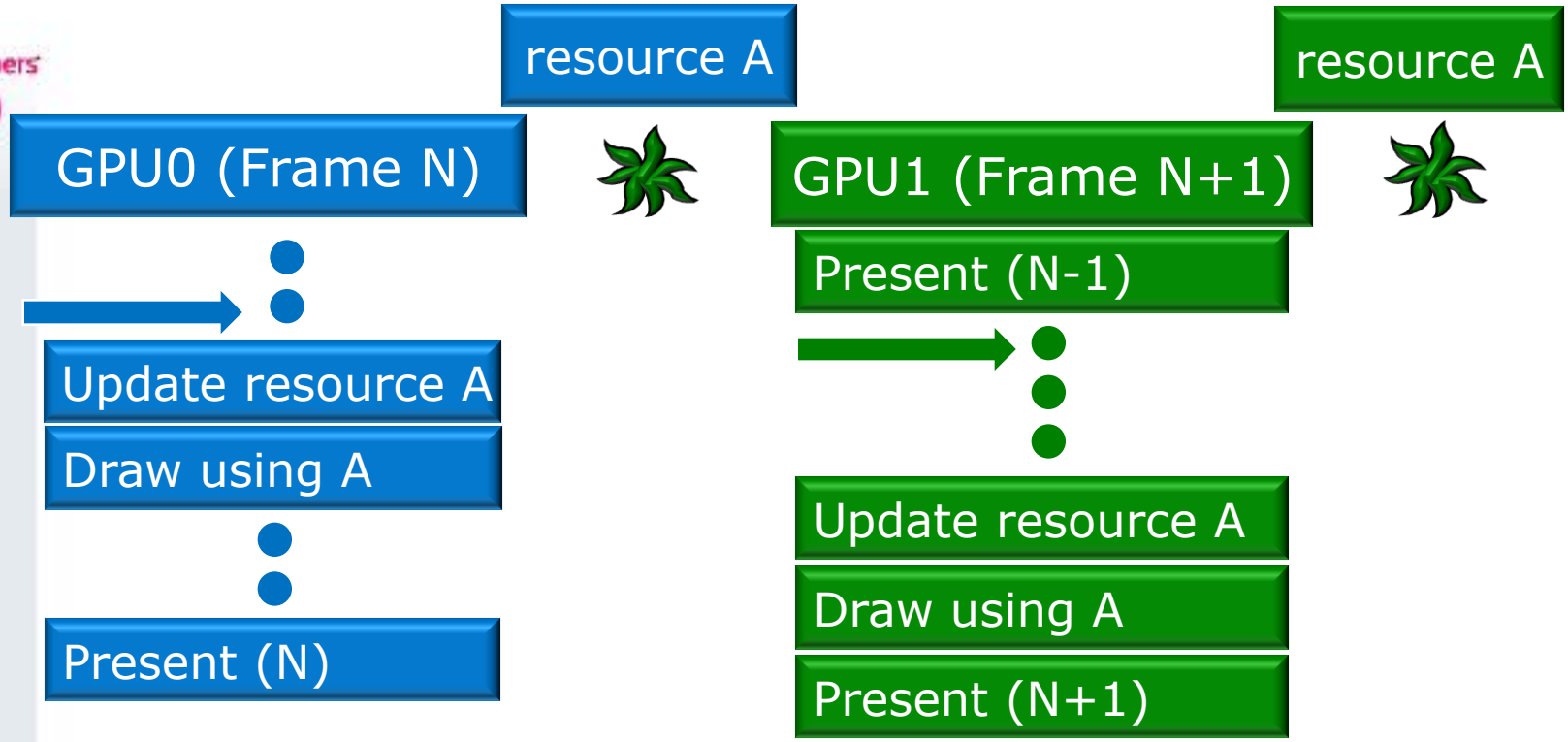
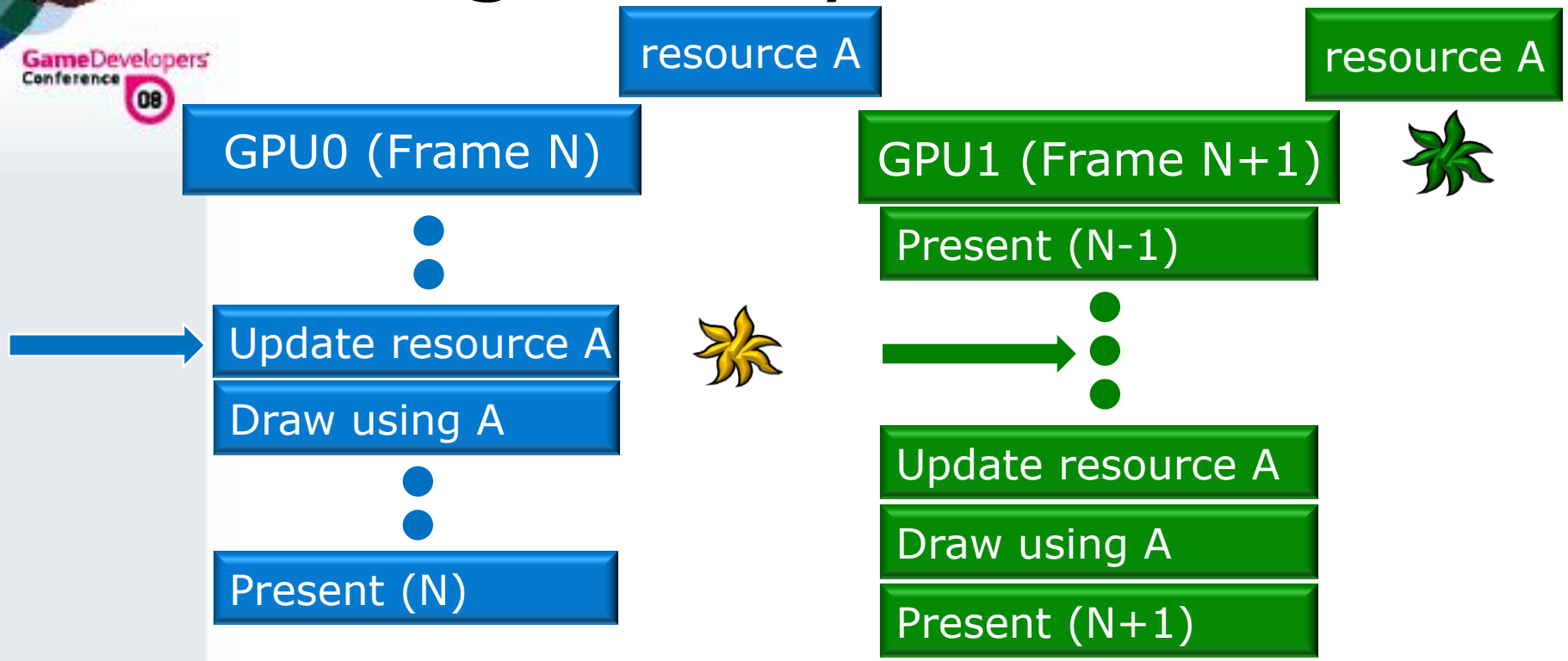
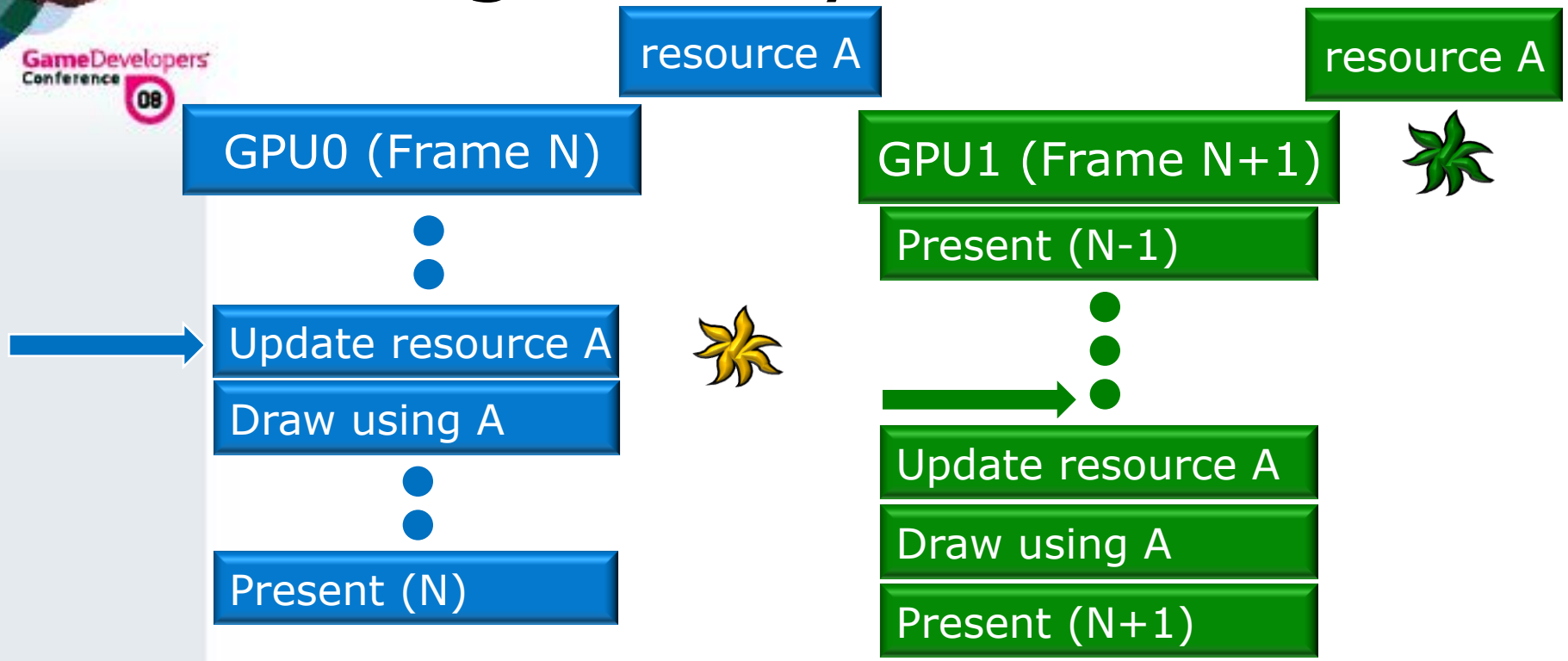



resource A
resource A
GPU0 (Frame N)
GPU1 (Frame N+1)
Present (N-1)
Update resource A
Draw using A
Update resource A
Draw using A
Present (N)
Present (N+1)

Solution: Resources that Change Every Frame



Solution: Resources that Change Every Frame



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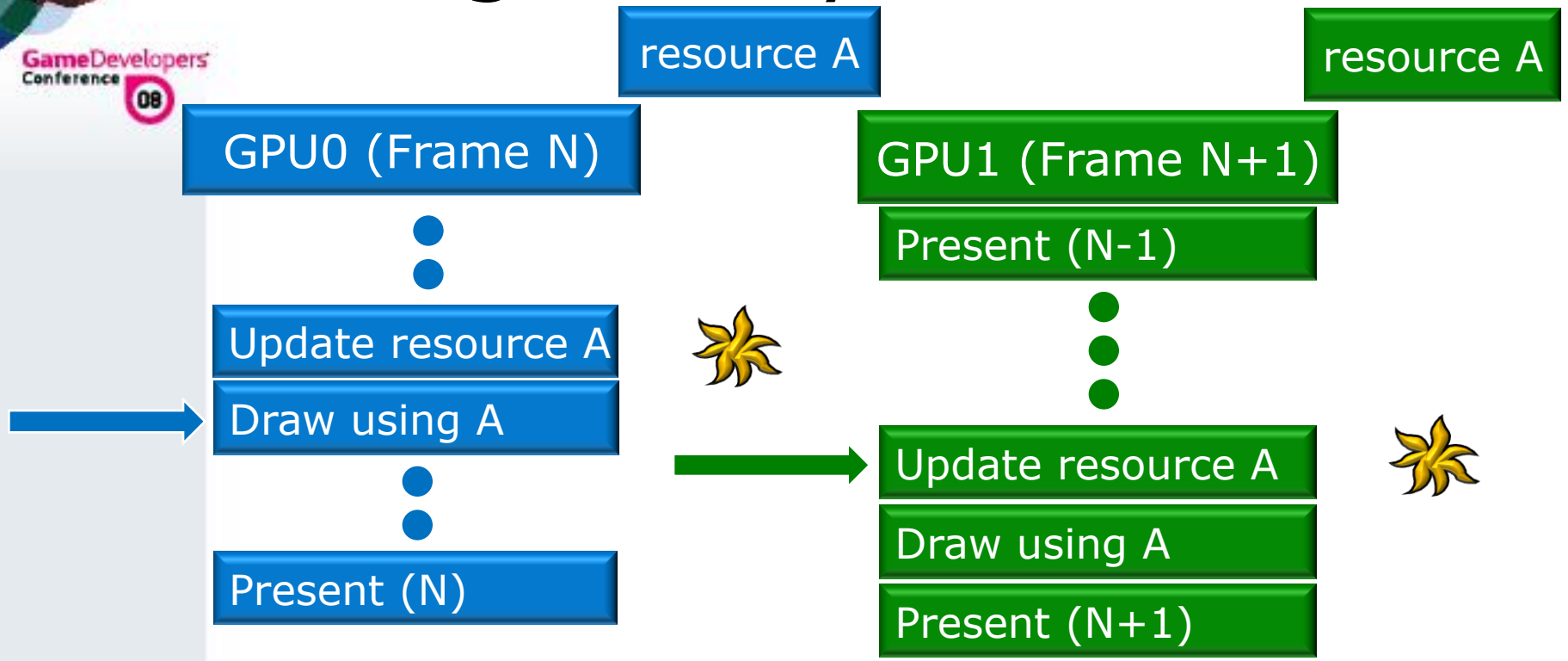

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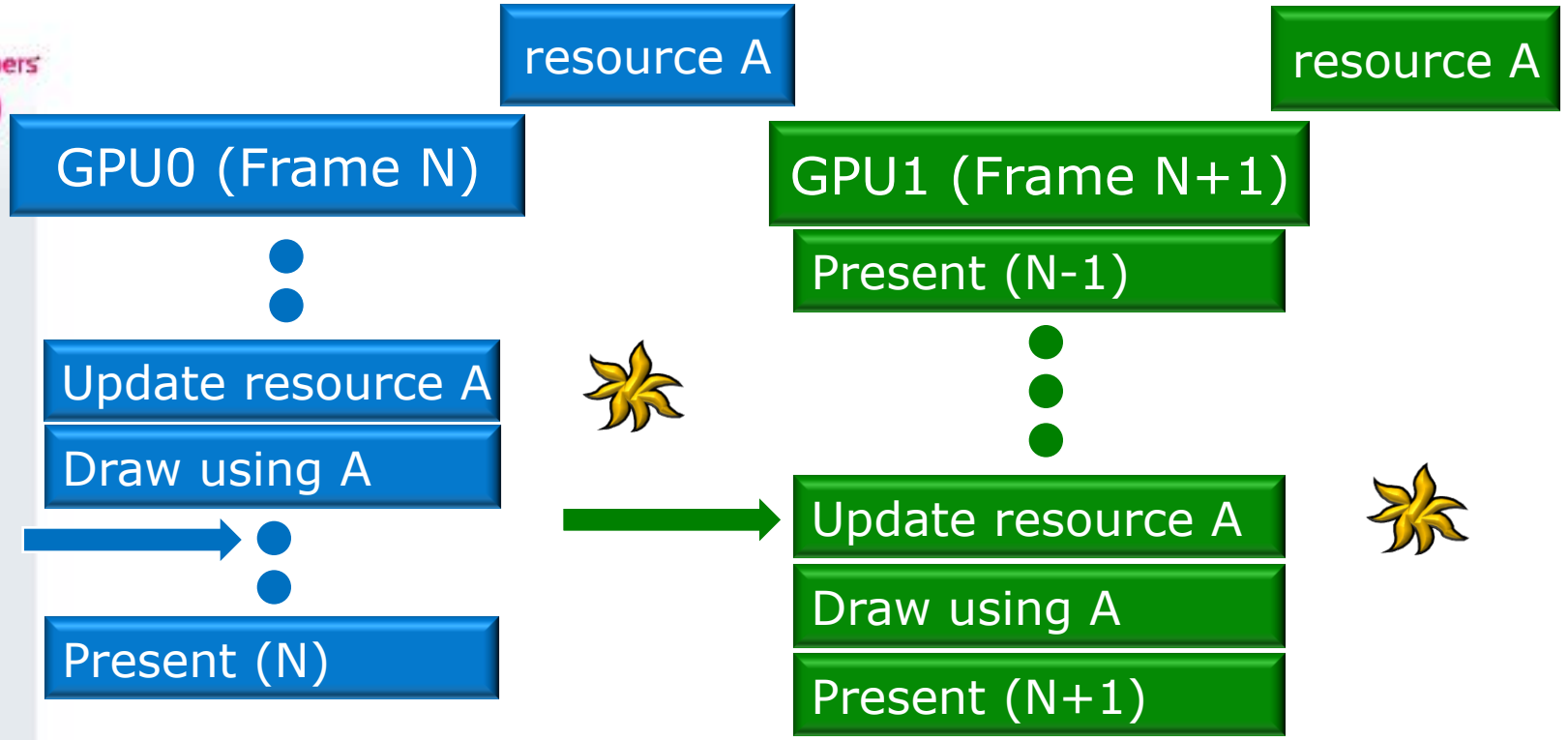

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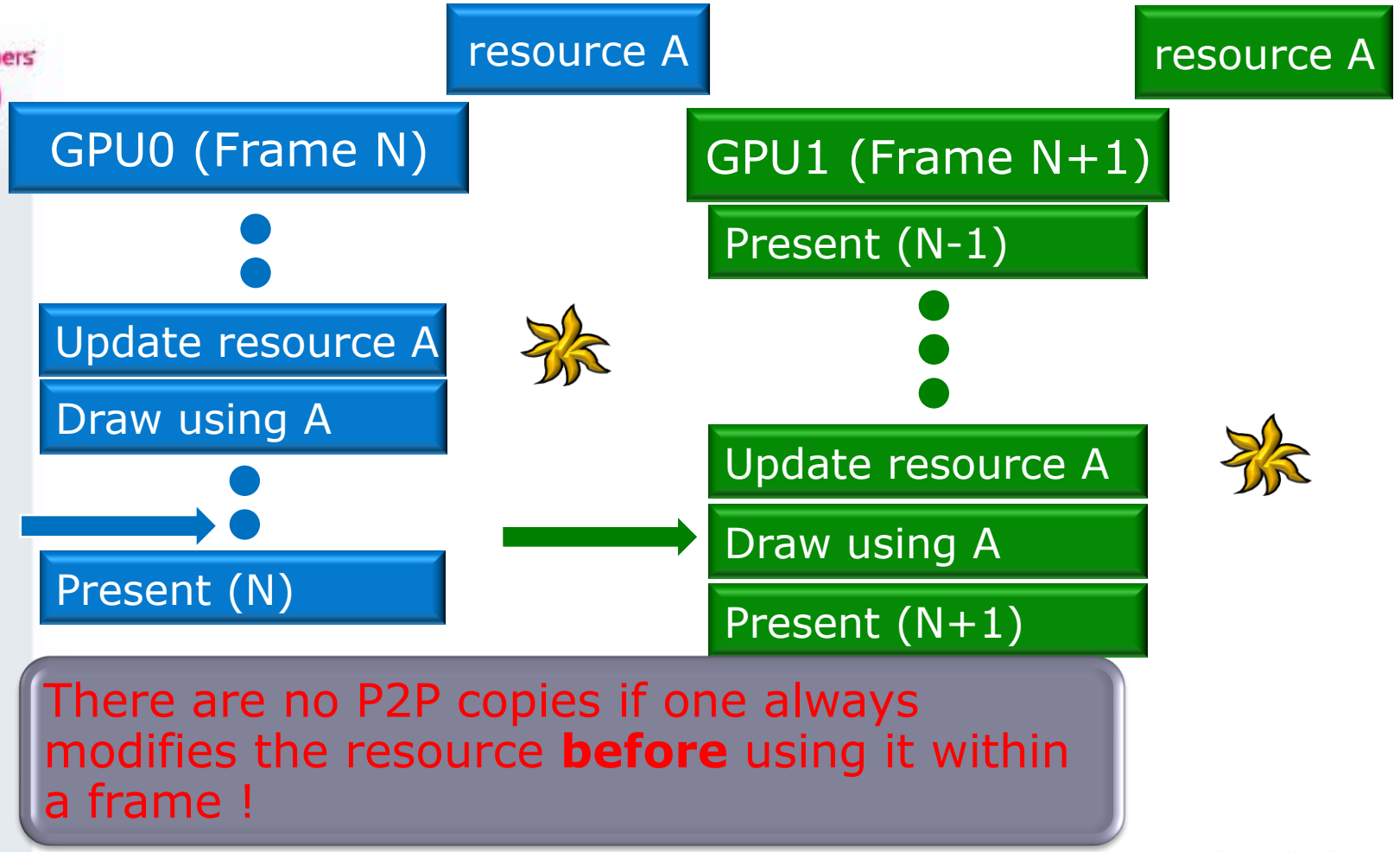
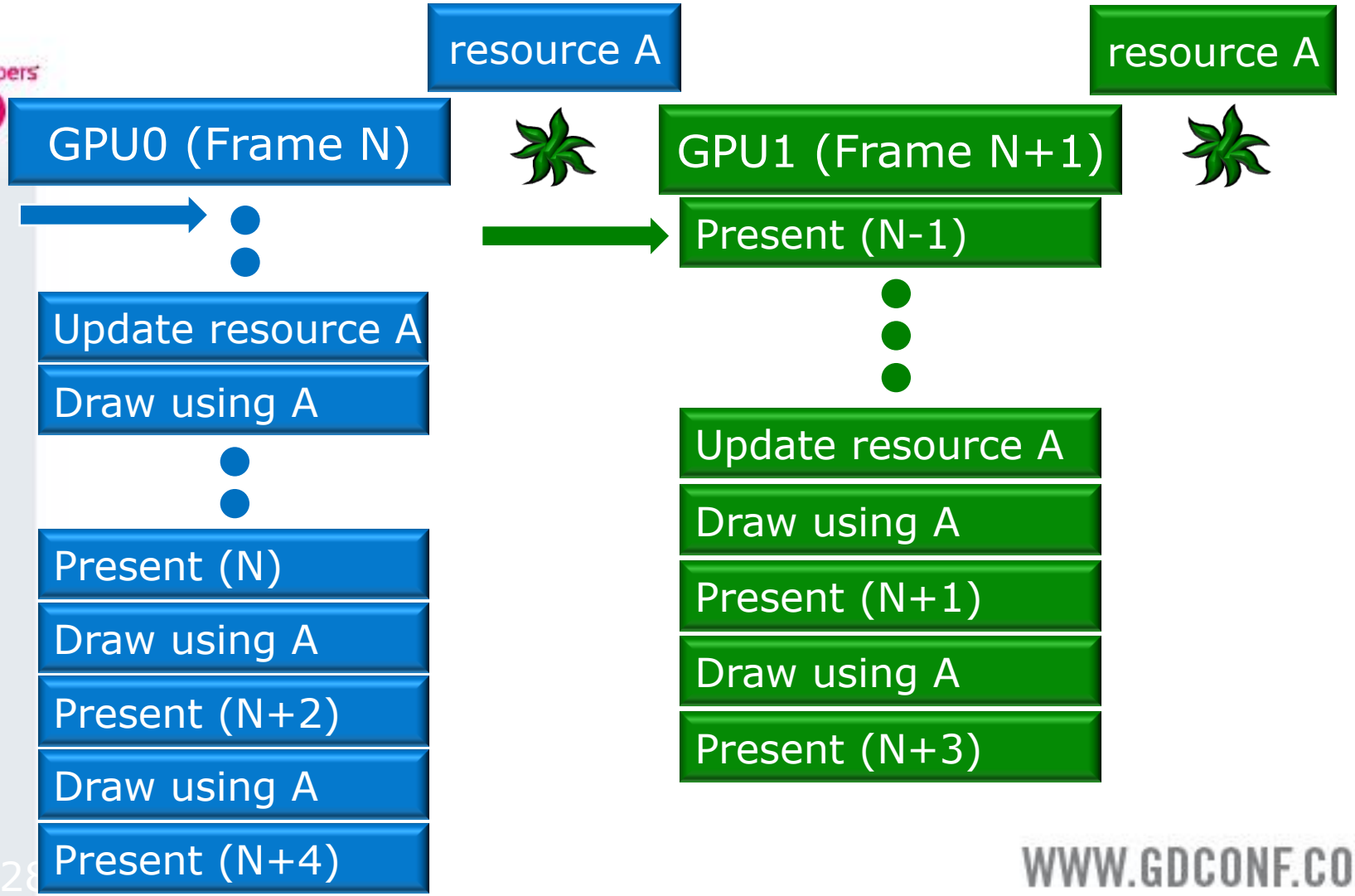


There are no P2P copies if one always modifies the resource **before** using it within a frame !

Solution: Resources that Change Every Few Frames



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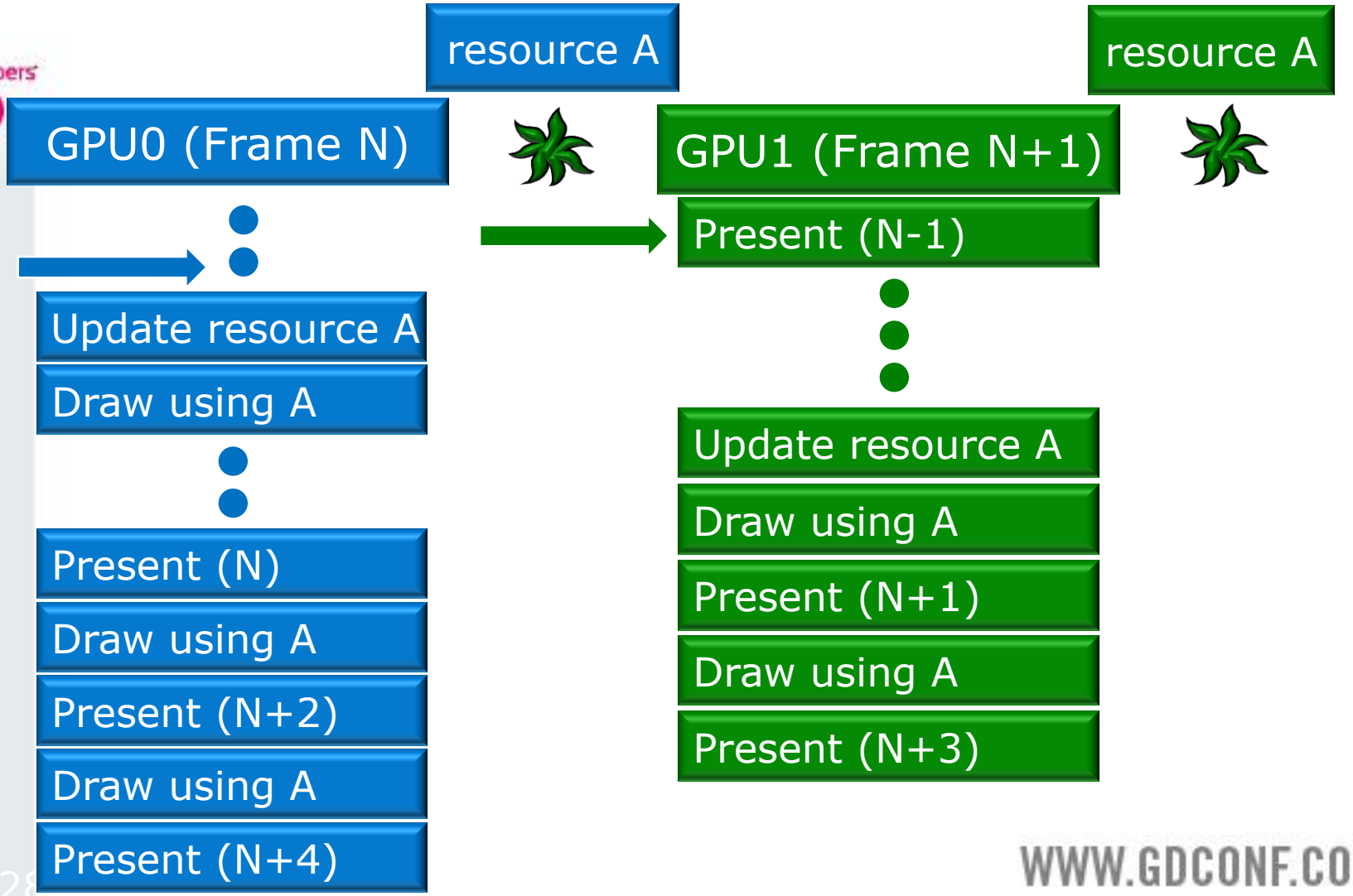

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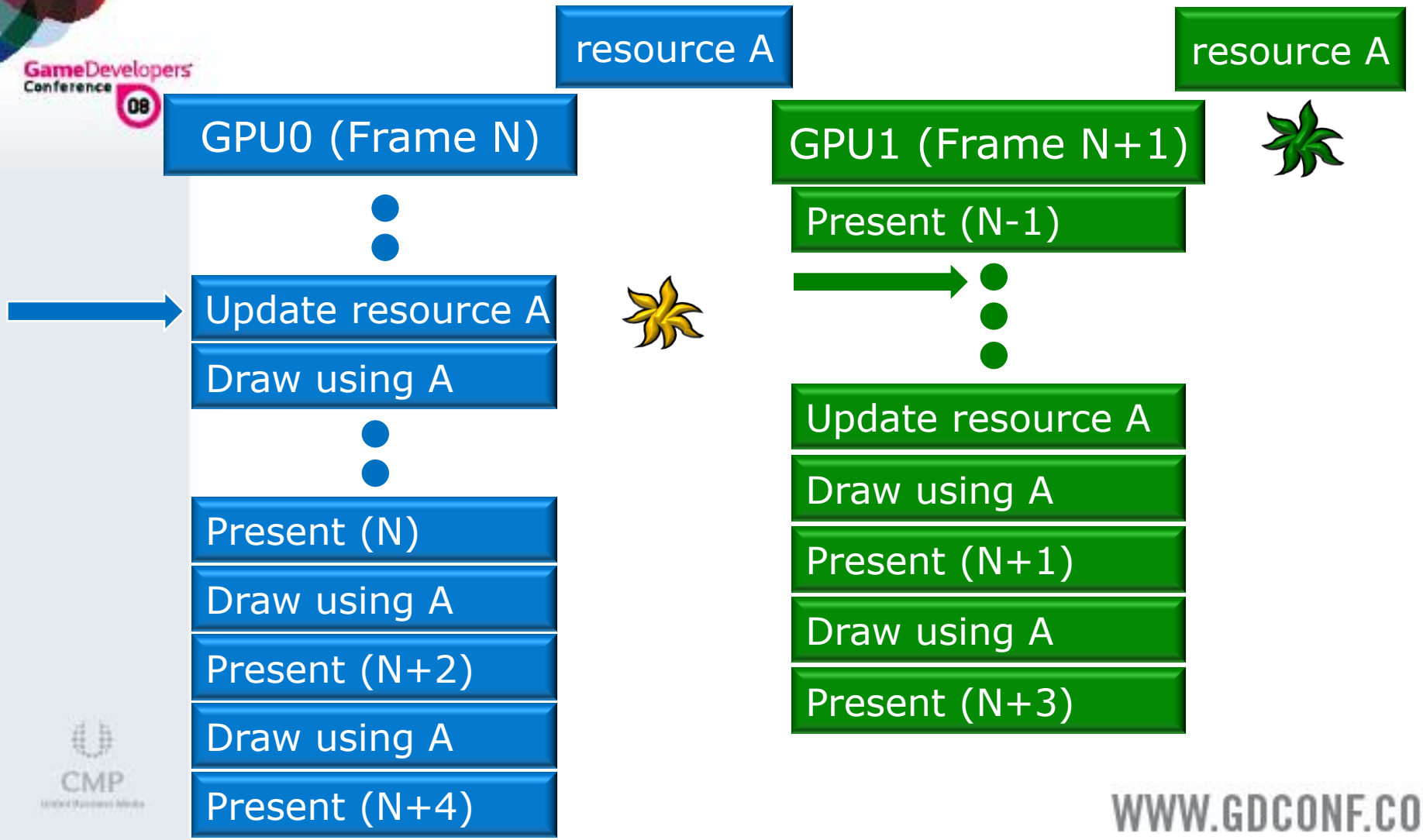

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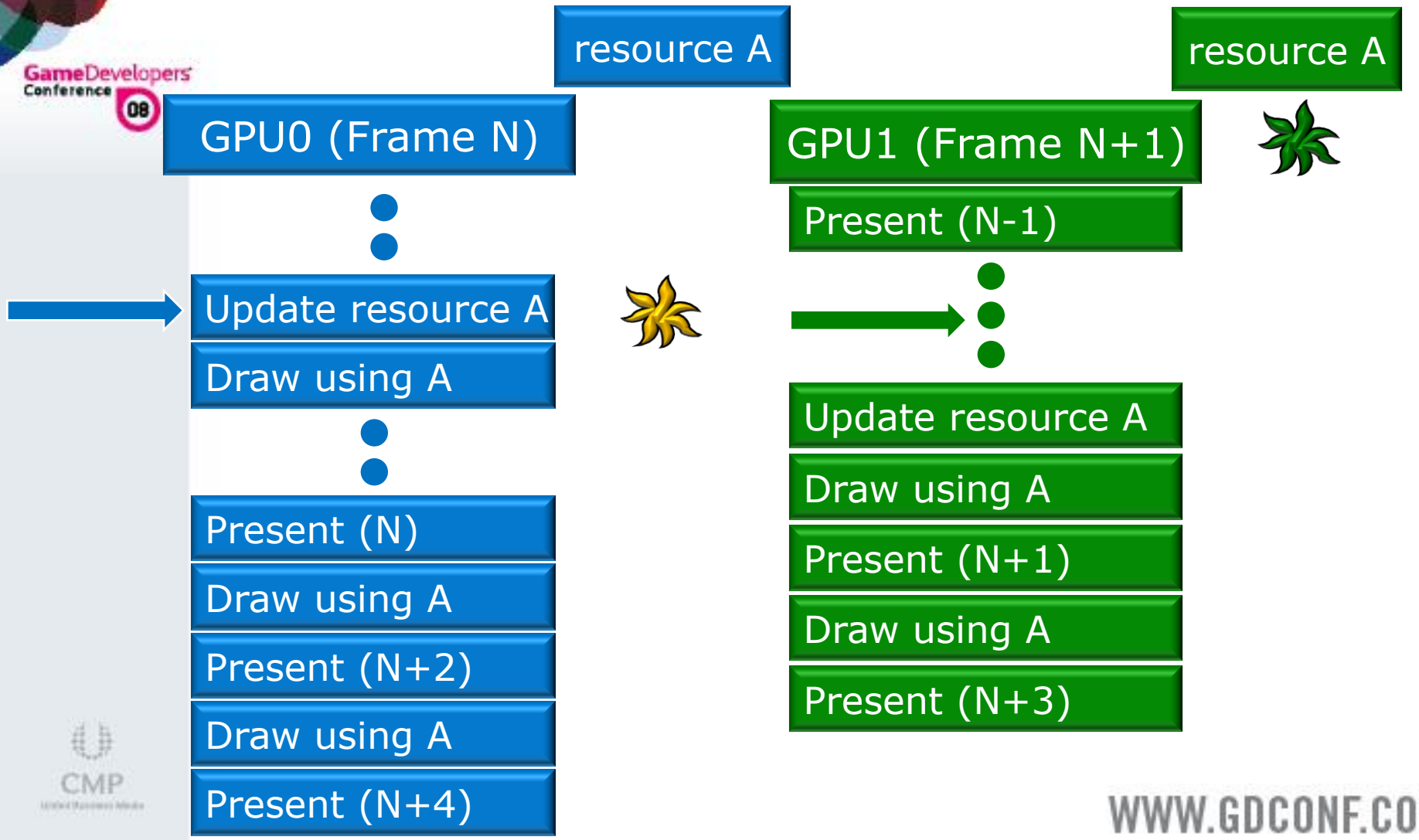

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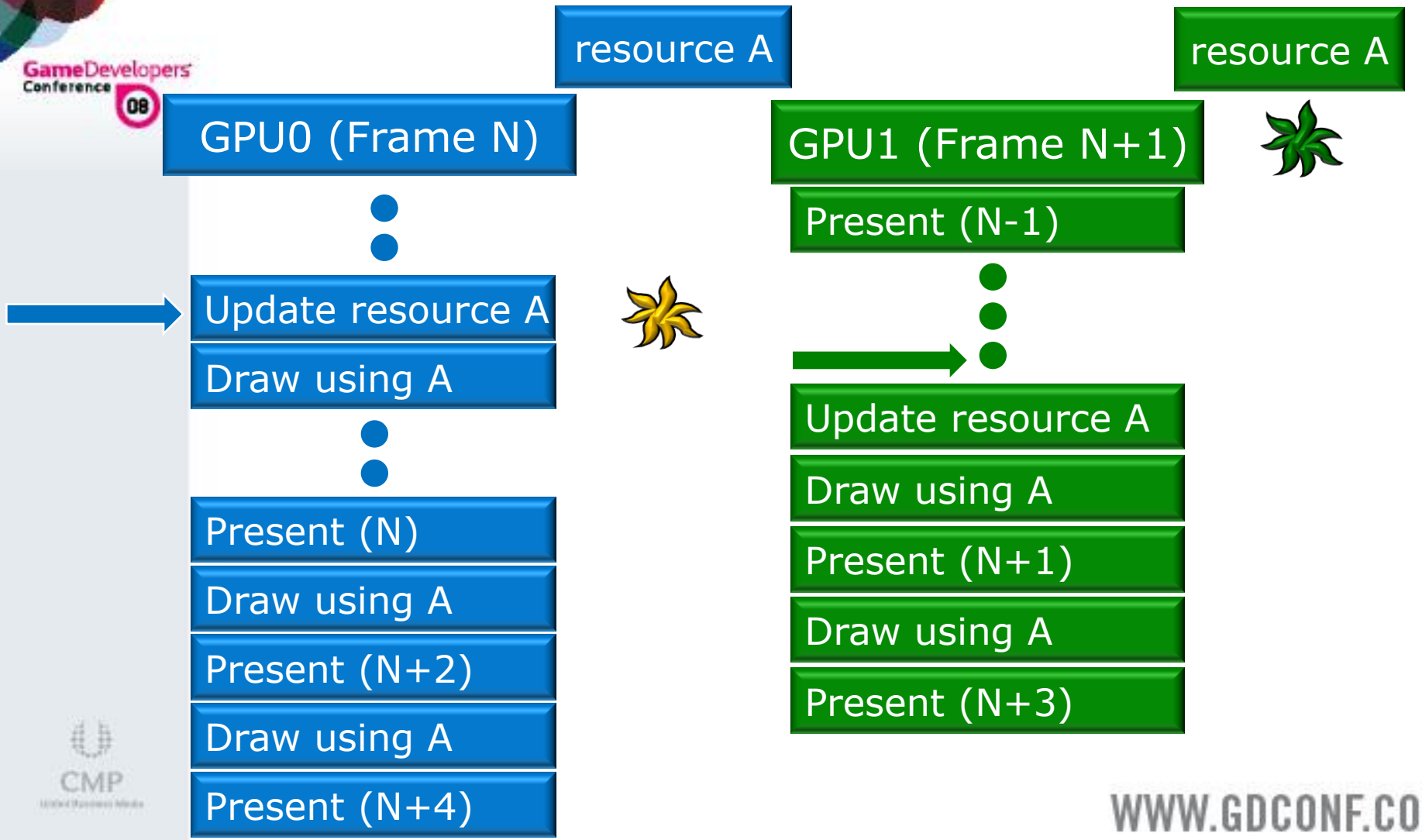

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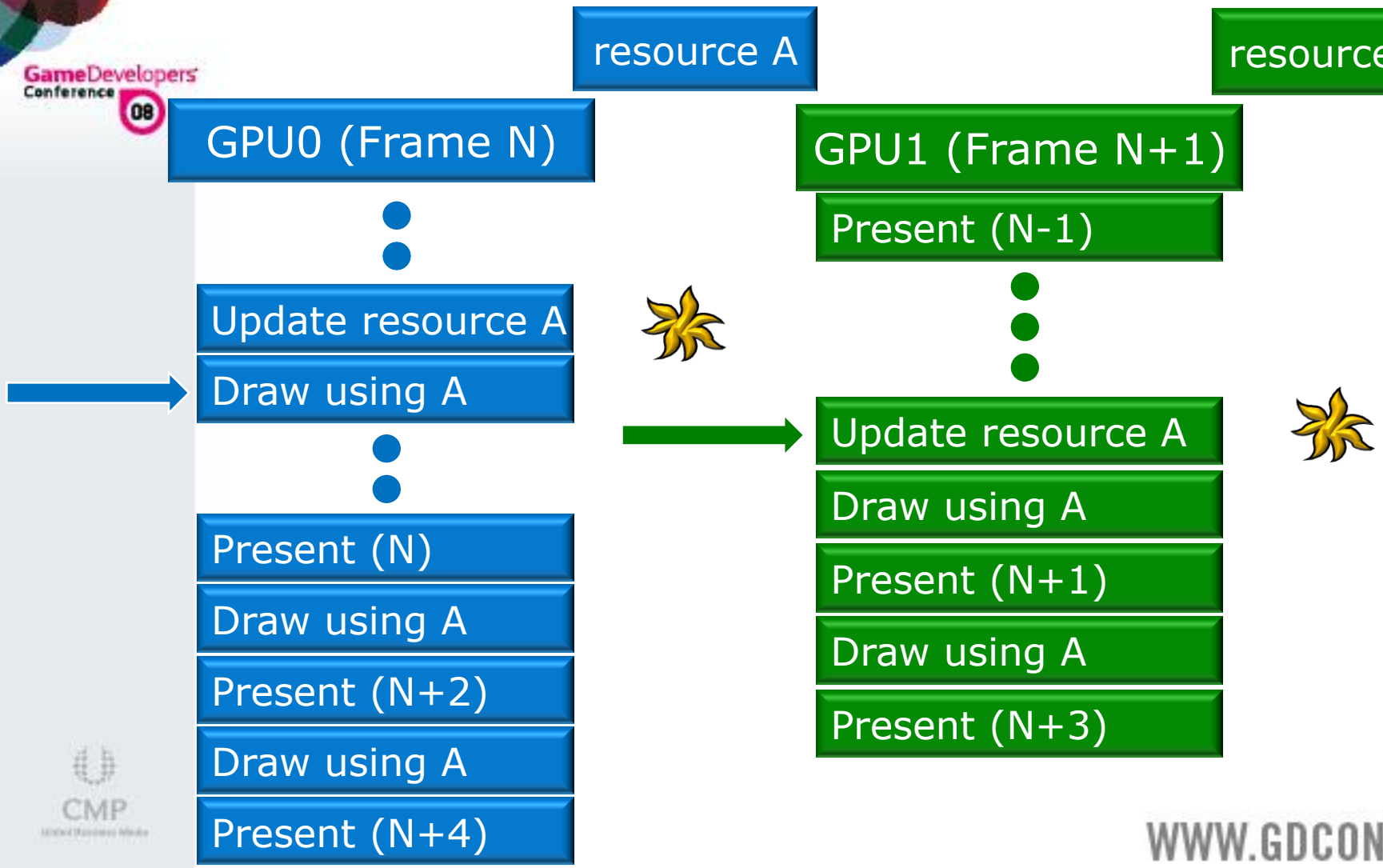
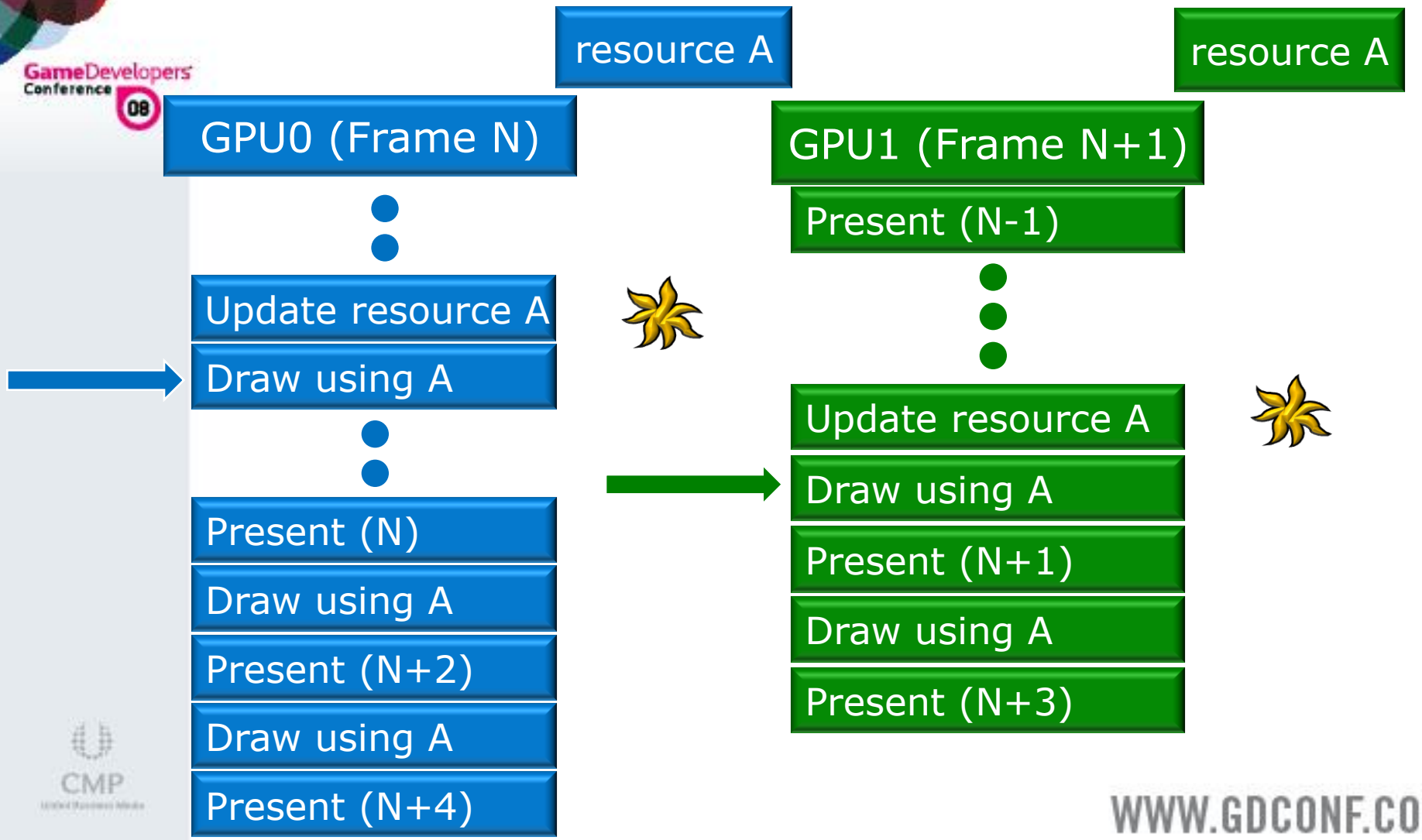


Solution: Resources that Change Every Few Frames



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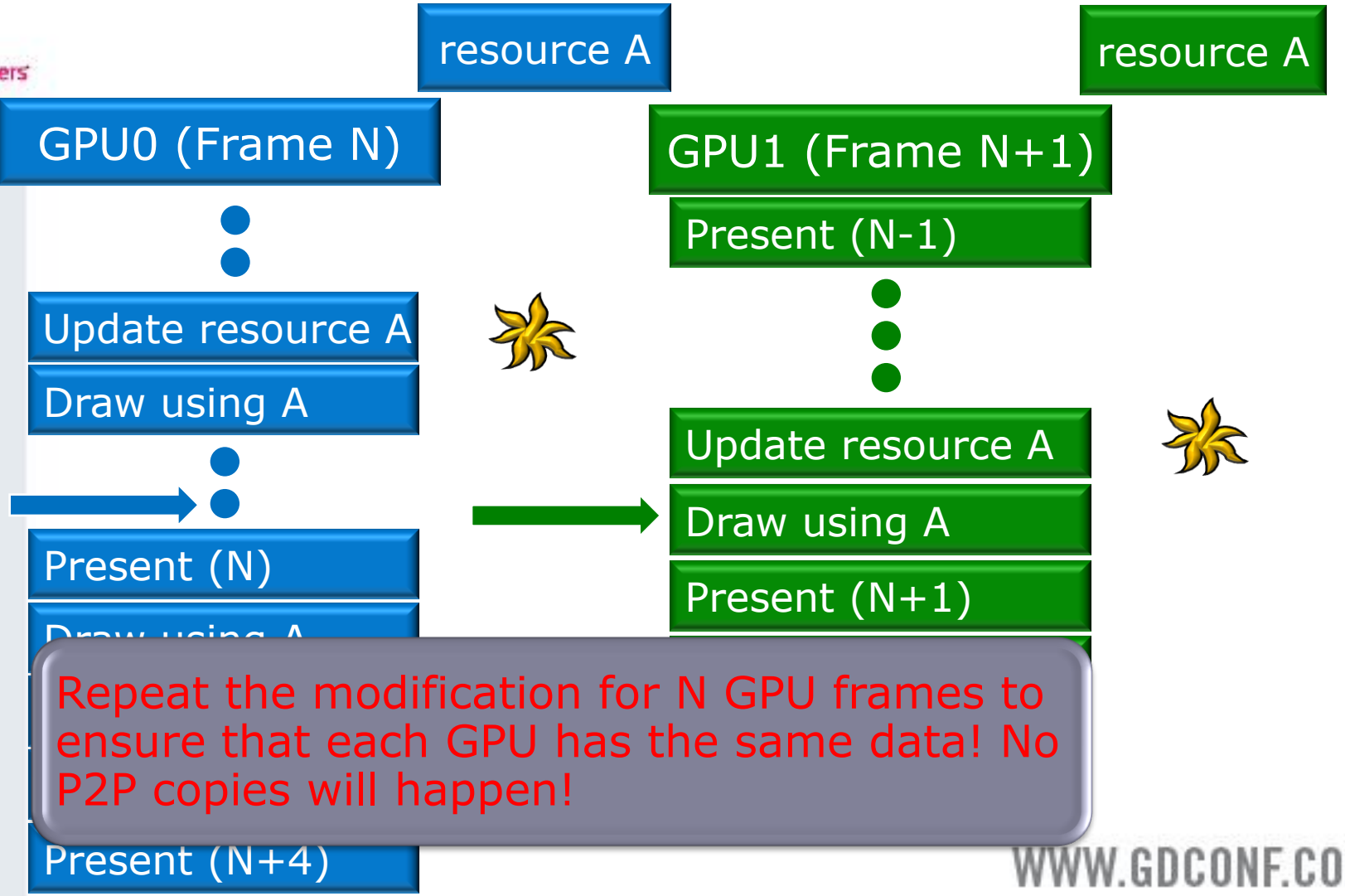


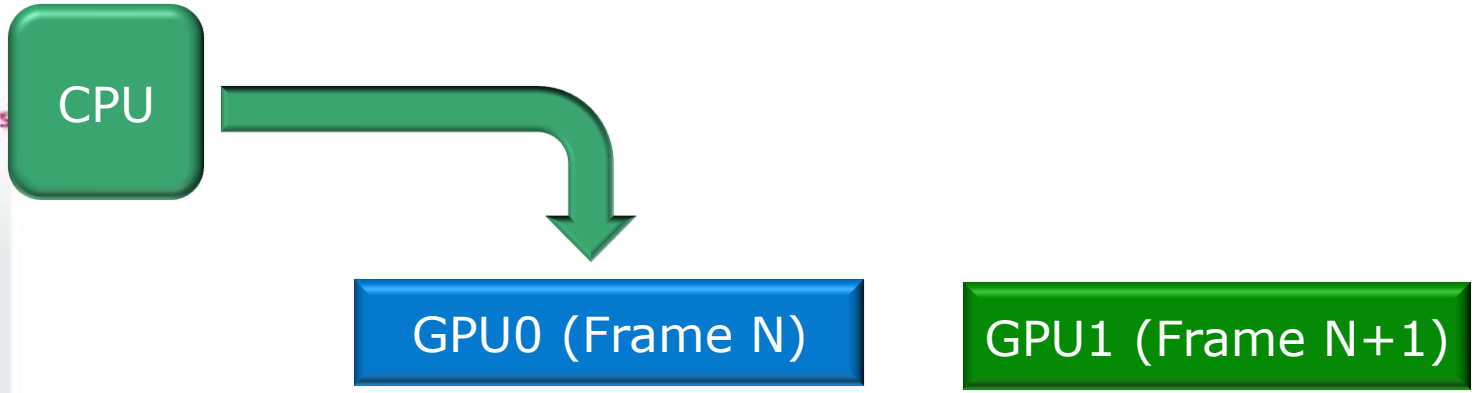
Preventing P2P copies

- NVIDIA: Make sure to Clear RTs that don‘t need to be in sync
- NVIDIA: Use Map(WRITE_DISCARD) to also hint resources that don‘t need to be in sync

Pitfalls: In DX10 there are Other Ways to Update Resources...

- Drawing to vertex/index buffers
- Stream Out
- CopyResource() calls
- CopySubresourceRegion() calls
- GenerateMips() calls
- ResolveSubresource() calls
- Do not use same resource as destination of both Map(WRITE_DISCARD) and CopyResource/CopySubresourceRegion calls

Pitfall: Waiting on Queries



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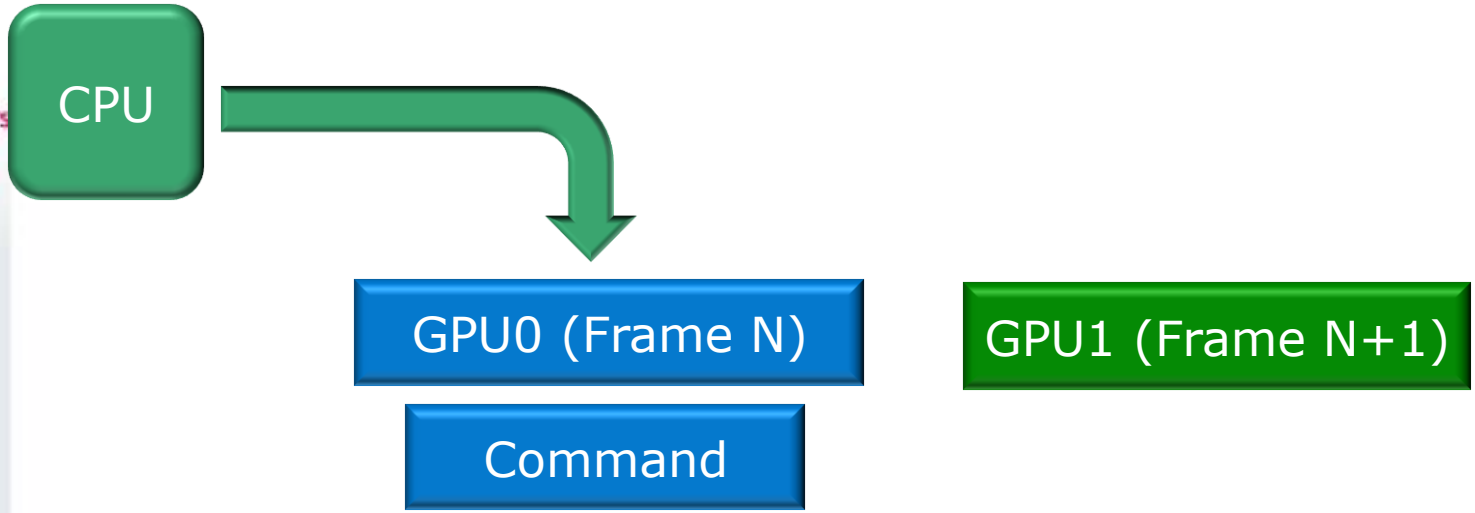
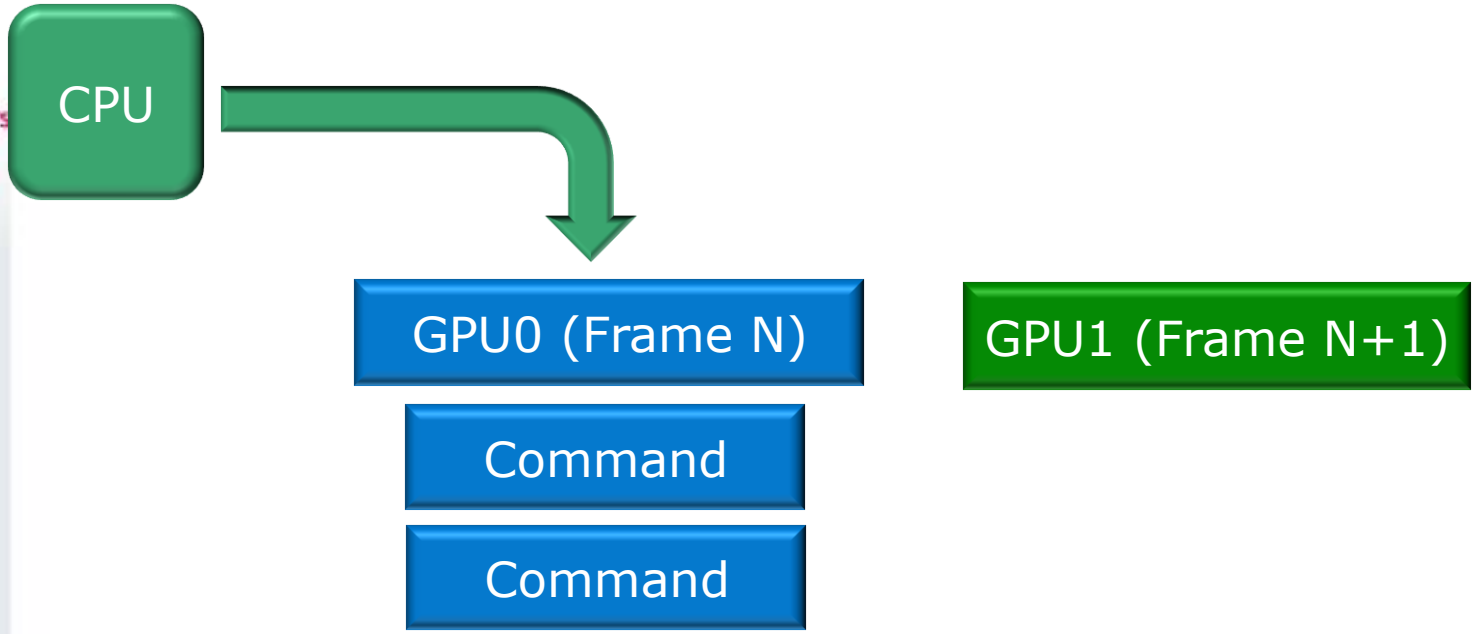
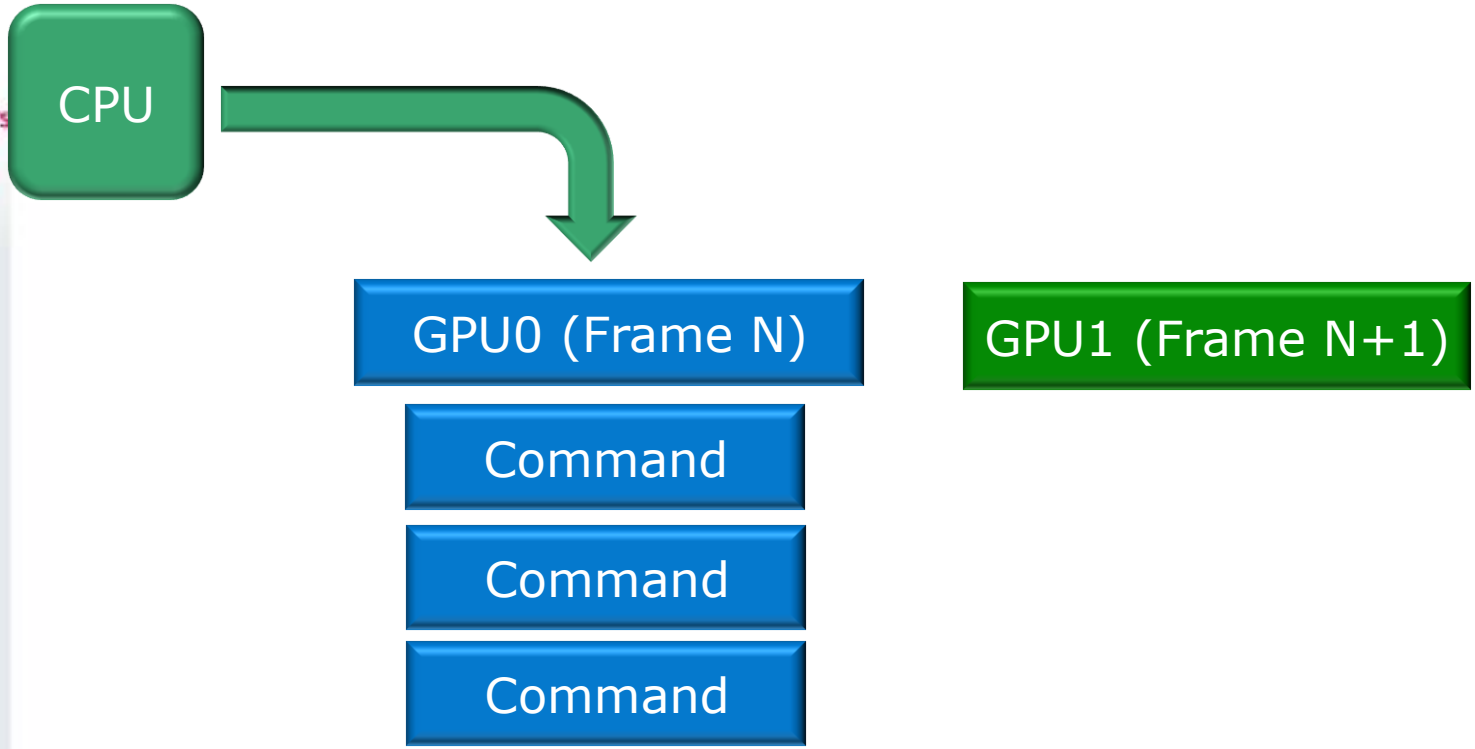


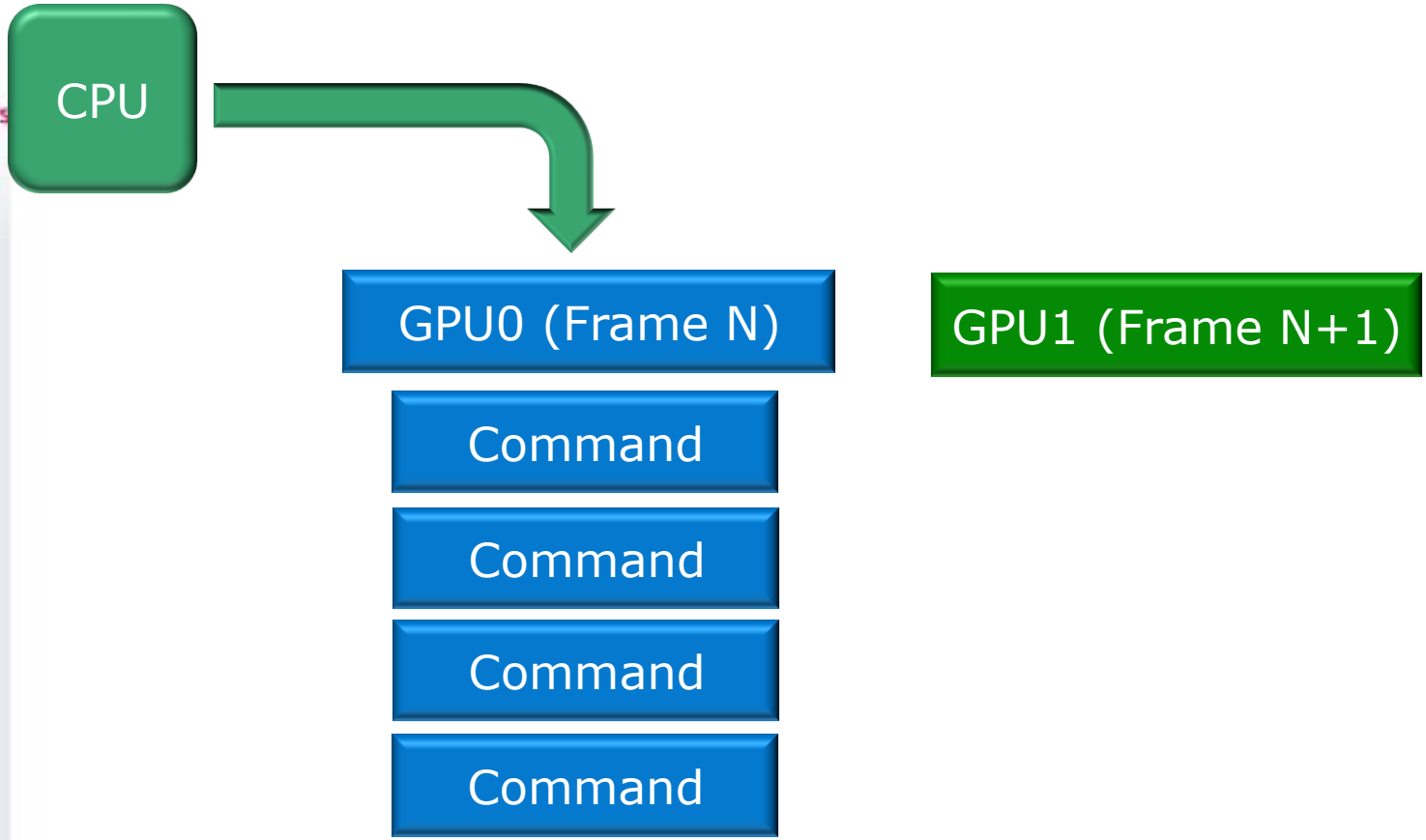
Pitfall: Waiting on Queries



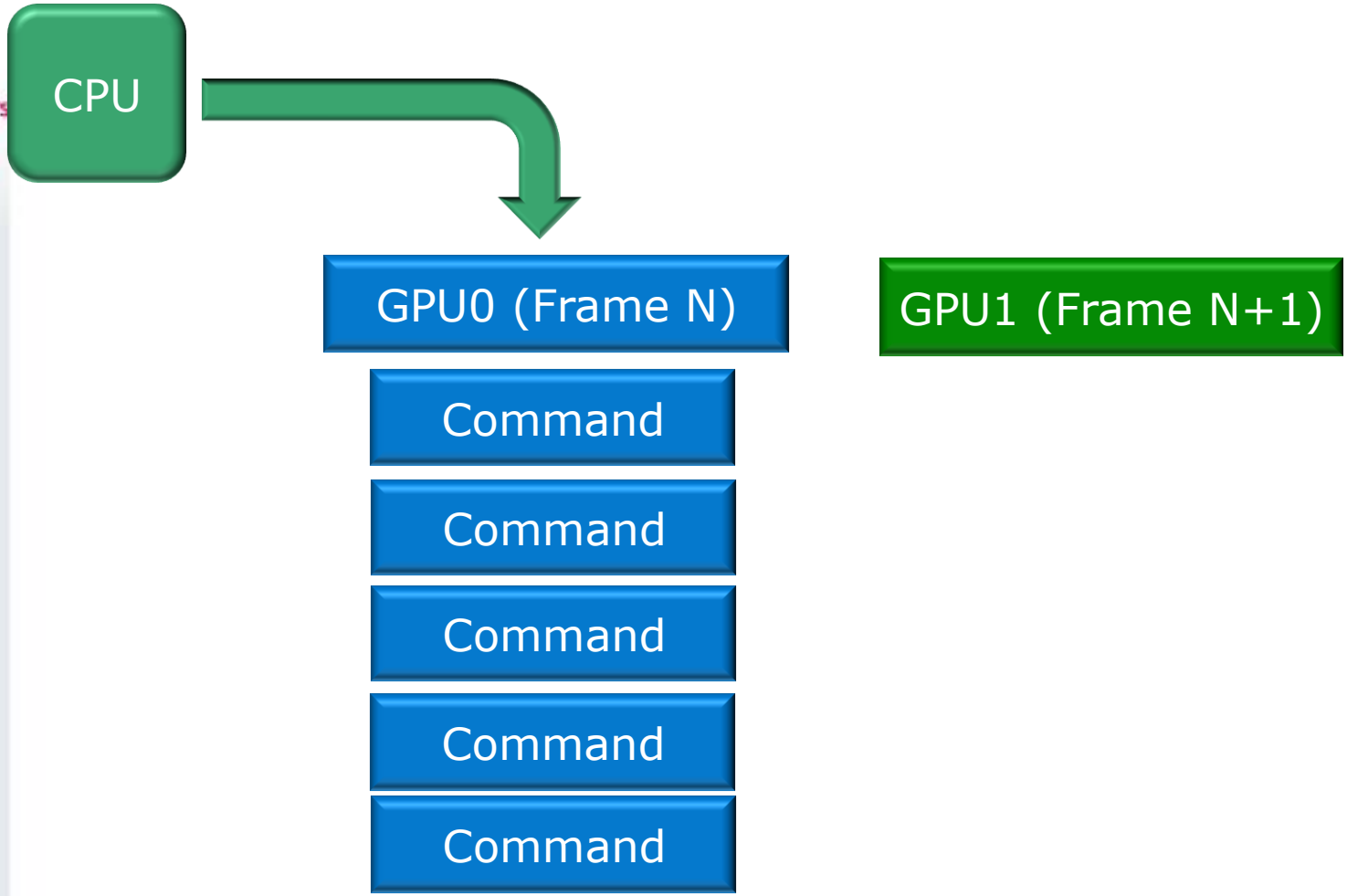
Pitfall: Waiting on Queries



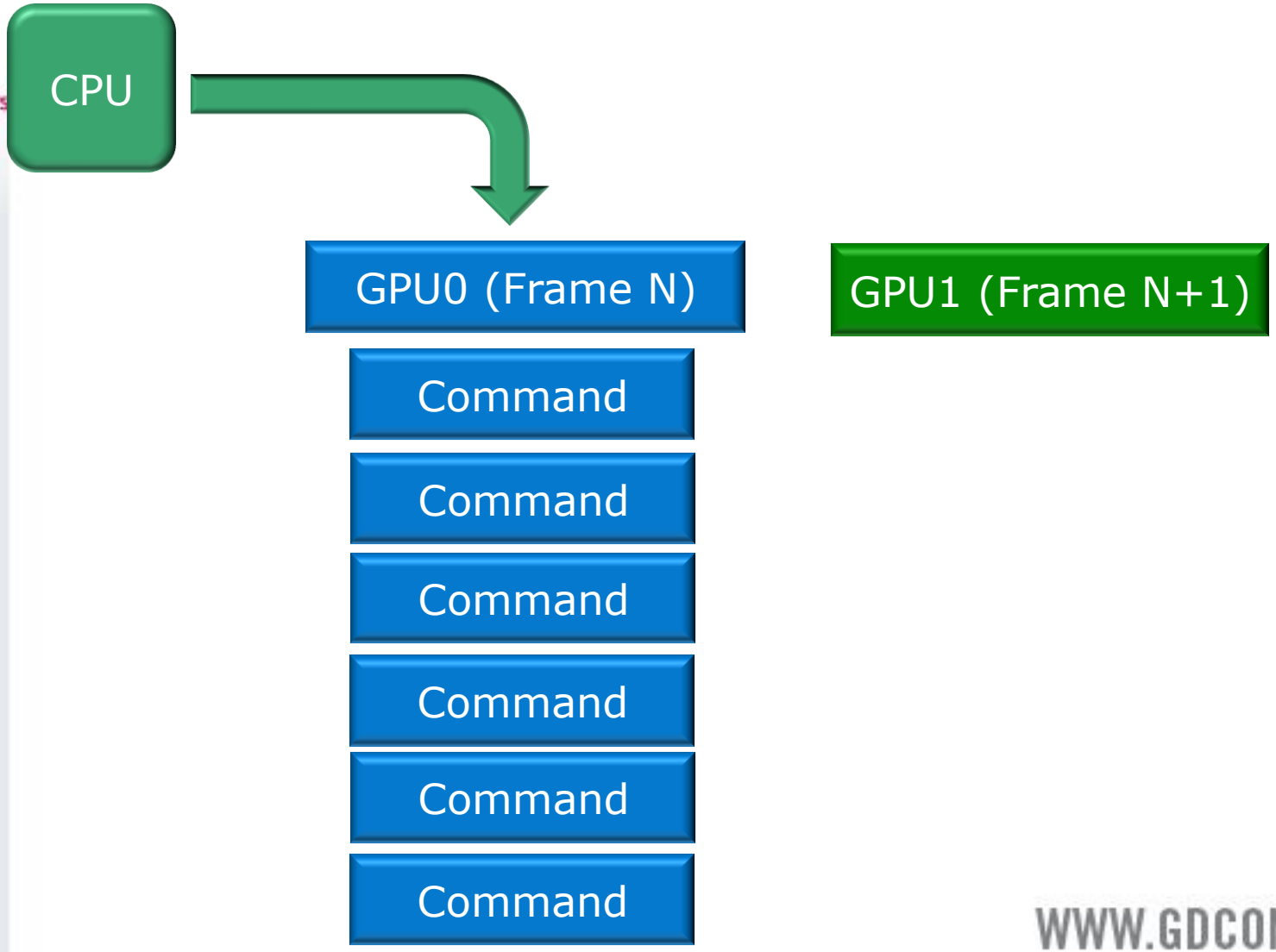
Pitfall: Waiting on Queries



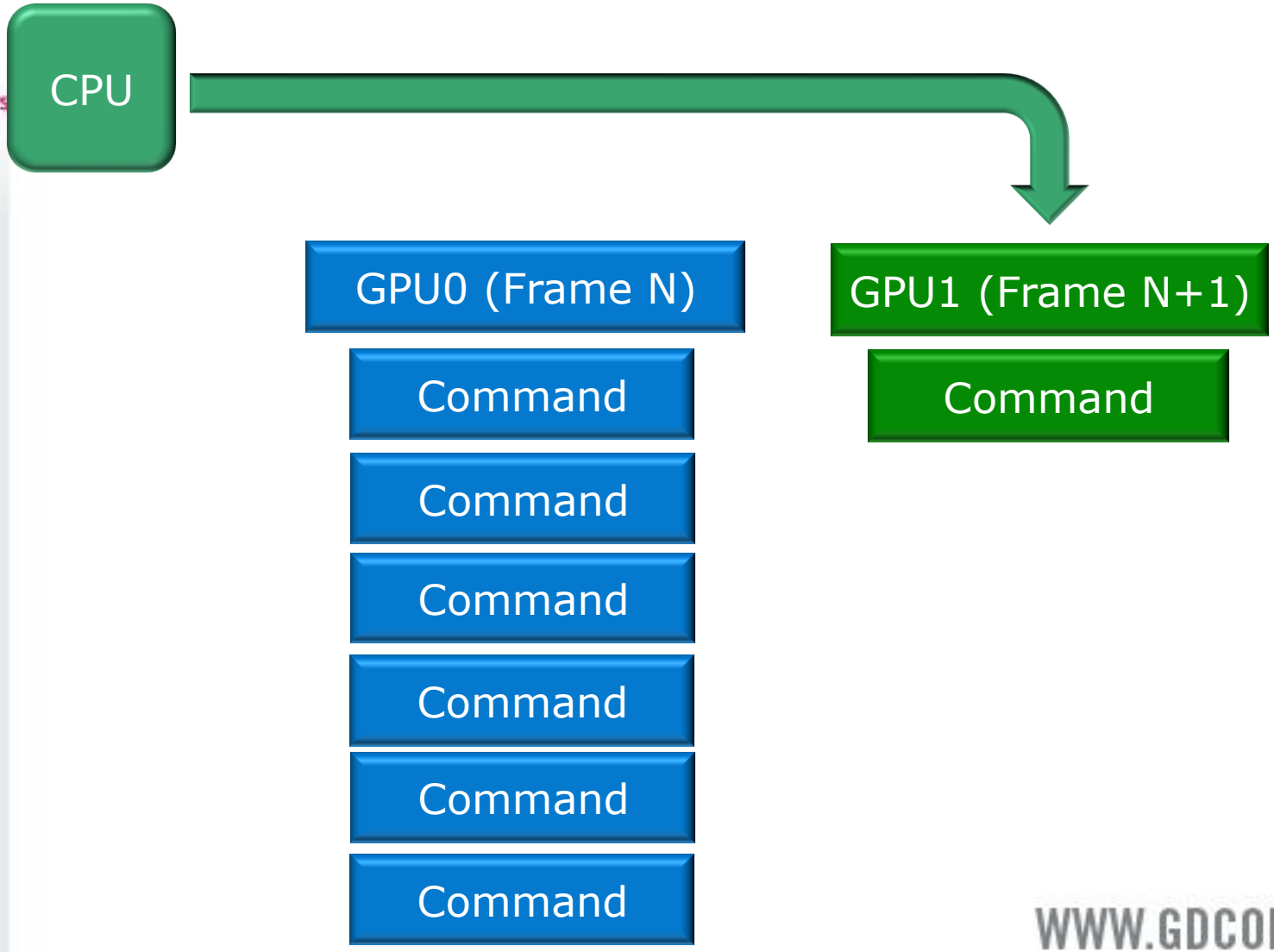
Pitfall: Waiting on Queries



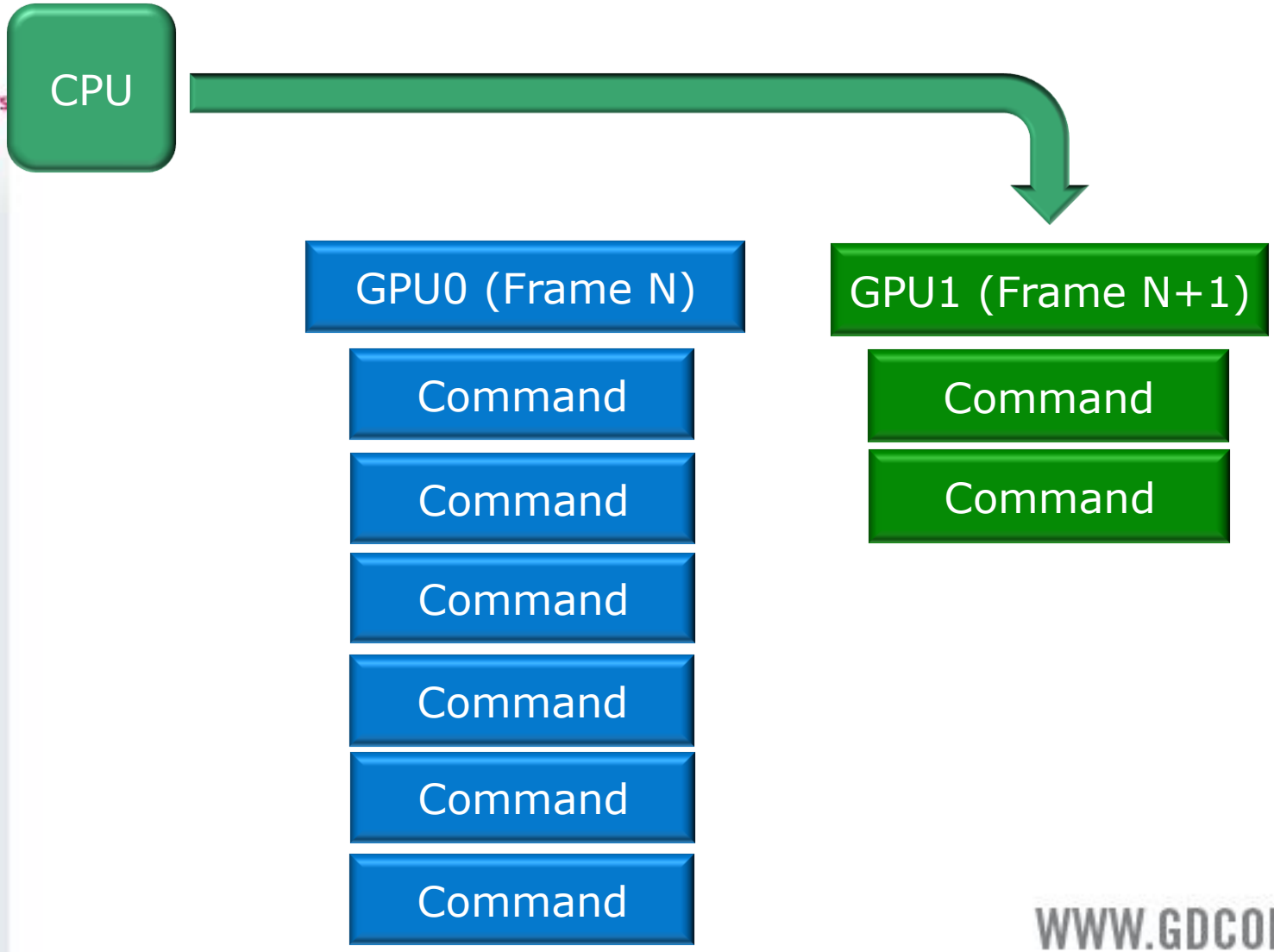
Pitfall: Waiting on Queries



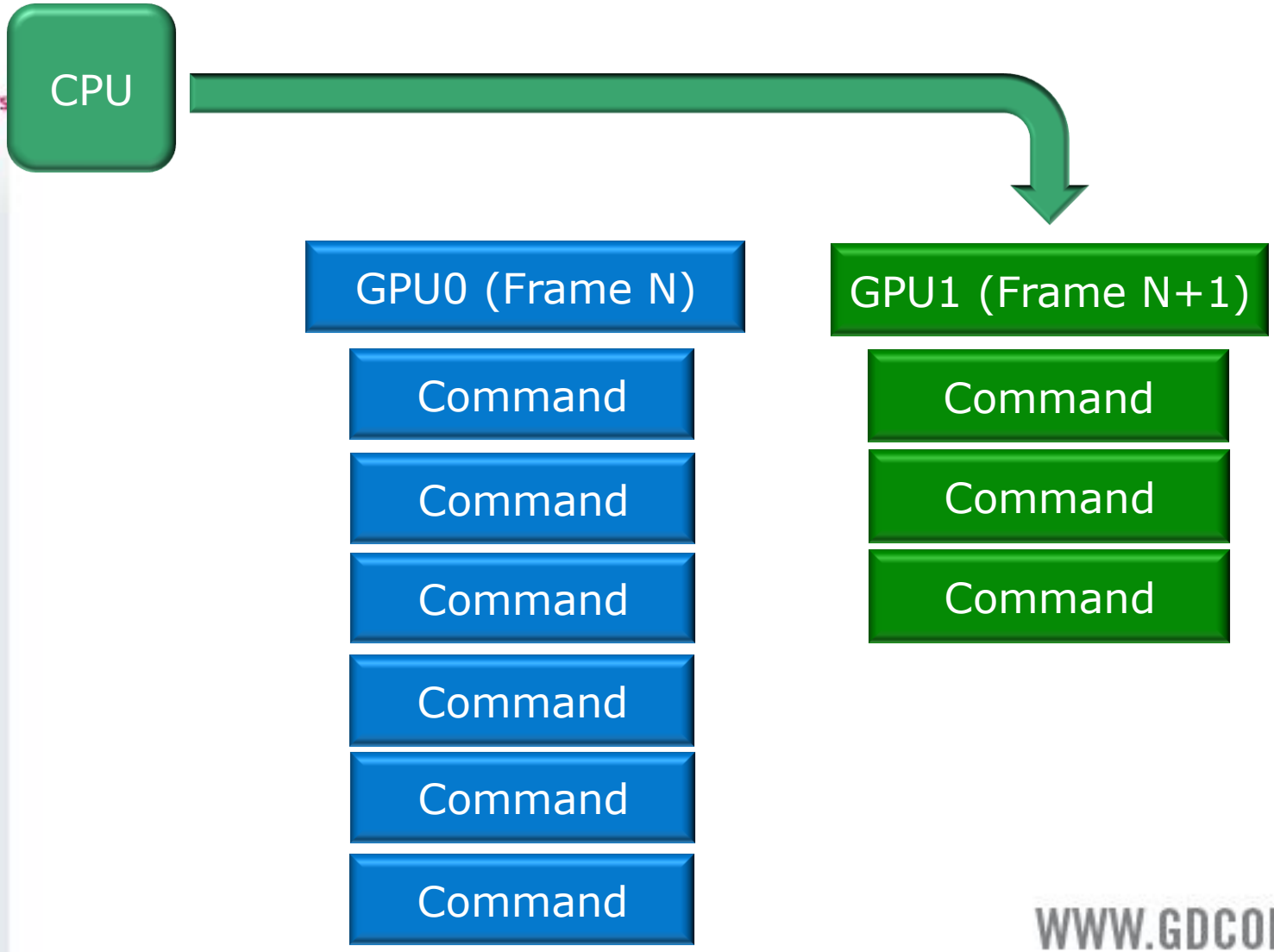
Pitfall: Waiting on Queries



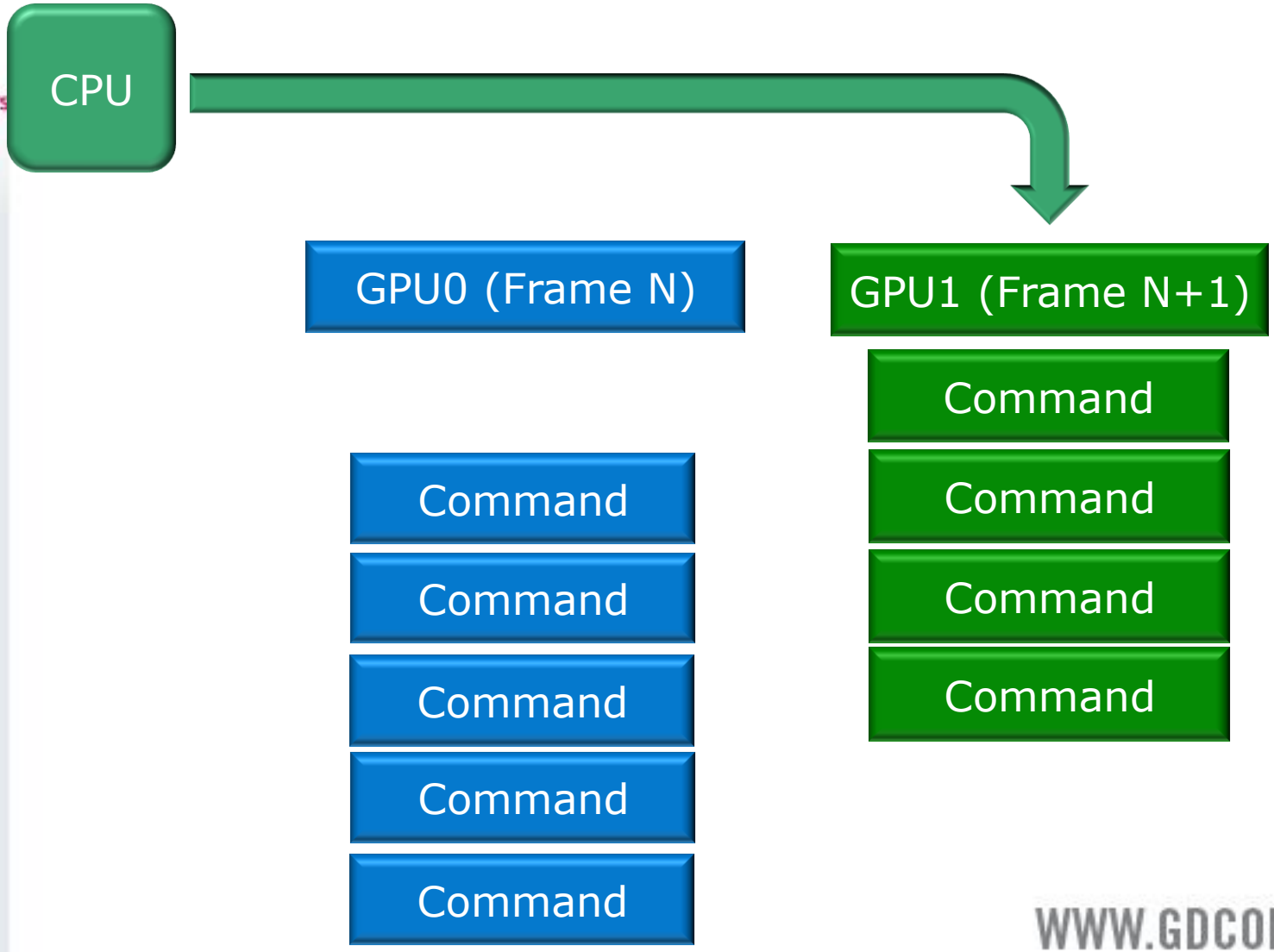
Pitfall: Waiting on Queries



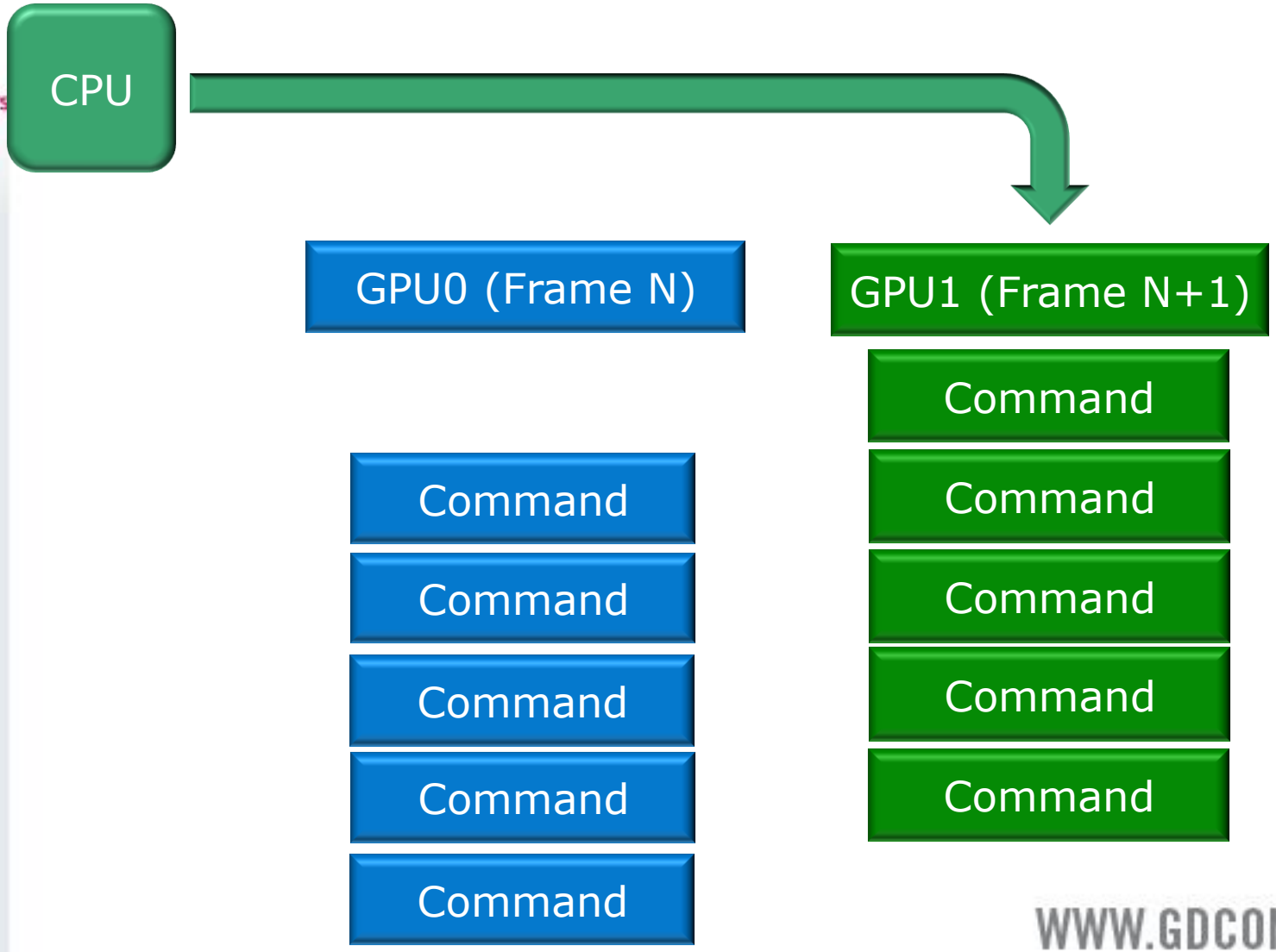
Pitfall: Waiting on Queries



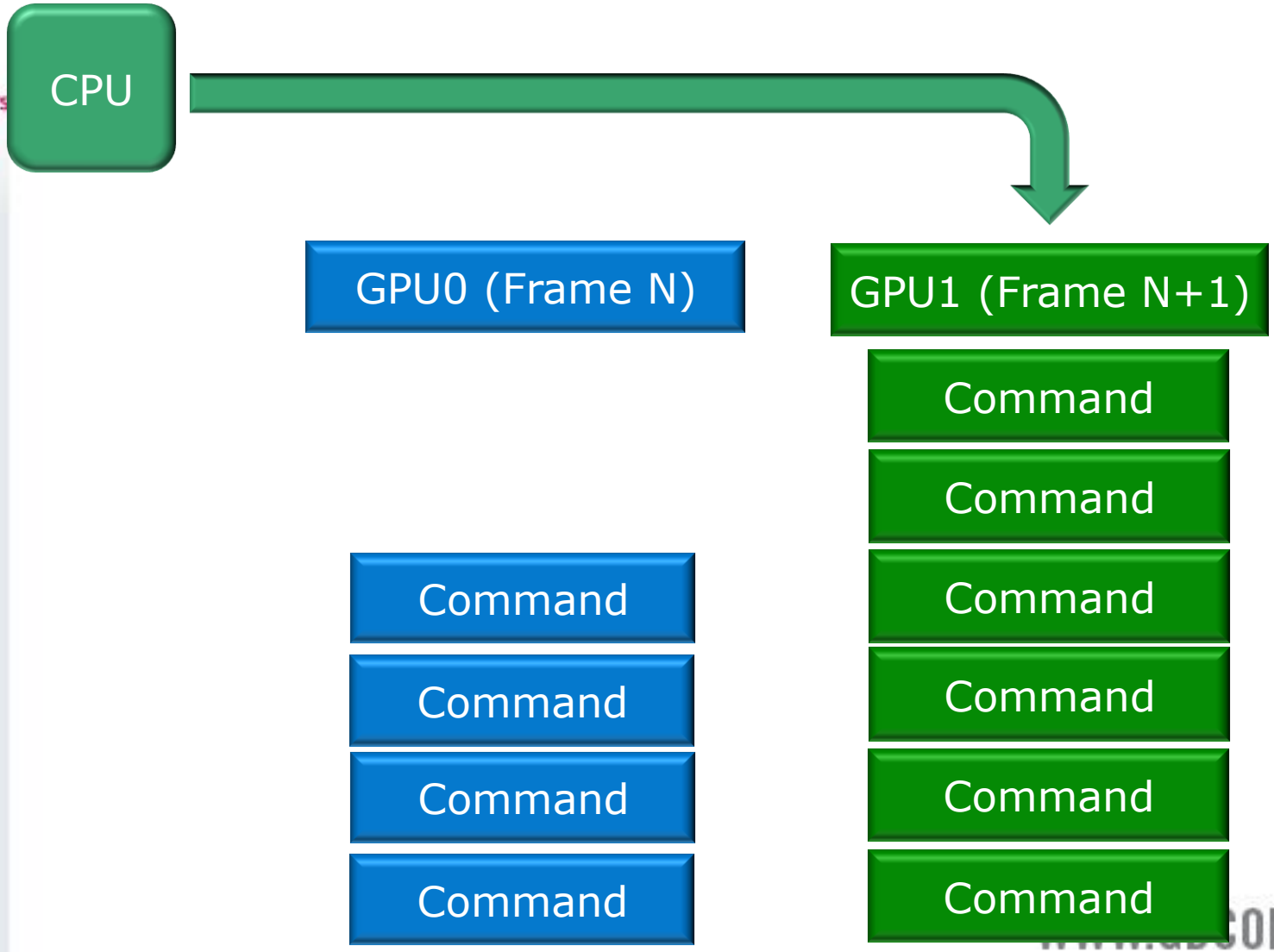
Pitfall: Waiting on Queries



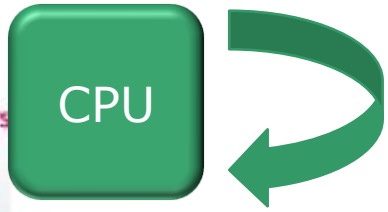
Pitfall: Waiting on Queries



Pitfall: Waiting on Queries



Pitfall: Waiting on Queries



Waiting for Query Result!!!

GPU0 (Frame N)

GPU1 (Frame N+1)

Command

Command

Command

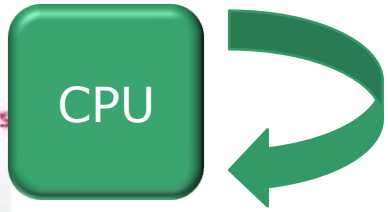
Command

Command

Command

Command

Pitfall: Waiting on Queries



Waiting for Query Result!!!

GPU0 (Frame N)

GPU1 (Frame N+1)

Command

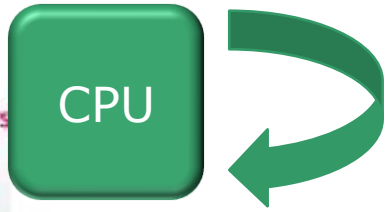
Command

Command

Command

Command

Pitfall: Waiting on Queries



Waiting for Query Result!!!

GPU0 (Frame N)

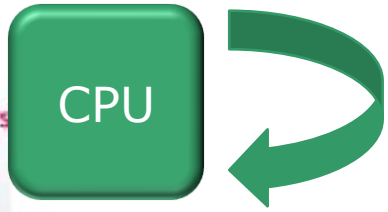
GPU1 (Frame N+1)

Command

Command

Command

Pitfall: Waiting on Queries

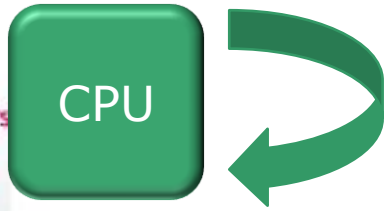


Waiting for Query Result!!!

GPU0 (Frame N)

GPU1 (Frame N+1)

Pitfall: Waiting on Queries



Waiting for Query Result!!!

GPU0 (Frame N)

GPU1 (Frame N+1)

Waiting starves GPU queues

Waiting limits parallelism

Waiting => CPU limitation

Solutions for Queries

- Avoid using queries wherever possible
- Make sure that a matched pair of BeginQuery / EndQuery calls occur within the same frame
- Avoid waiting on query results
- For queries issued every frame
  - Create additional query objects for each GPU
  - Cycle through them
- Pickup the result of a query at least N-GPU frames after it was issued
- For occlusion queries consider a CPU based approach

Pitfall: CPU Access to a Renderable Resource

- When the CPU locks a renderable resource it must wait for all GPUs to finish using the resource before acquiring the pointer
- All GPUs now have to wait until the CPU unlocks the resource pointer
- After the unlock the driver has to update the resource on each GPU via P2P copies
- Just don't do this – it destroys performance even on a single GPU setup, and is catastrophic for MGPUs

Solutions: Locks / Maps

- In DX10 stream to and copy from STAGING textures
- In DX9 StretchRect() is always better than Lock()
- At resource creation time use the appropriate flags from:
  - D3D10_USAGE
  - D3D10_CPU_ACCESS_FLAG
- AMD:In DX9 never lock static Vertex/Index Buffers because it will cause P2P copies

Concluding Pitfalls & Solutions

- Drivers take a conservative approach
  - Performing P2P copies
- You know the application best
  - Determine if a P2P copy is necessary
  - Talk to us about an app profile
- Never use resources shared between devices on DX10
  - No way to detect update by other app

Call to Action

- MGPUs provide demonstrable performance/quality gains even on low end setups
- Plan from day one to make your rendering scale
  - Use AMD library to detect number of GPUs
  - Use NVIDIA library to detect MGPU topology
- Regularly check for AFR unfriendly behavior
- Talk to us holger.gruen@amd.com
illamas@nvidia.com

Please Fill In The Feedback Forms

Questions?